BENTON HARBOR POWER PLANT LIMNOLOGICAL STUDIES

PART XVII. PROGRAM OF AQUATIC STUDIES RELATED TO THE DONALD C. COOK NUCLEAR PLANT

John C. Ayers

Erwin Seibel

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PROGRAM OF STUDIES RELATED TO THE DONALD C. COOK NUCLEAR PLANT

Abstract. The ecological monitoring program for the Donald C. Cook Nuclear Plant is presented from its developmental stages in 1966 to the anticipated monitoring of the environment during the plant's period of power production. The development of the environmental program provides an insight into the process of finally deciding on a satisfactory sampling scheme which provides a base of pre-operational data for comparison with operational data.

The sampling density and frequency as well as sample locations for the field program are given in tables and figures. For comprehensiveness the field and sampling methods for each of the elements of the biota under study is provided. The biota for which methods are described include bacteria, benthos, fish, fish eggs, fish larvae, aquatic macrophytes, periphyton, phytoplankton, psammon, and zooplankton.

Impingement and entrainment studies, in integral part of the environmental program, are designed to measure the possible impact of the plant on the passage through the plant of the biota. A supplemental program of visual observation by trained personnel provides the additional input of actual observations by divers of the biota in the proximity of intake and discharge structures, as well as in a control area located outside the plume. Chemical investigations of sediment, water and interstitial fluids are described giving both field and laboratory methods.

A listing of reports that have resulted from the voluminous amount of data is provided. These reports which present the data, discussions of the data, and interpretations of this data are considered an integral part of the overall environmental program presented.

INTRODUCTION

This report outlines the development of the comprehensive aquatic ecological studies that have been designed to measure the influence of the operation of a nuclear generating facility on southeastern Lake Michigan. Studies have been underway at the Donald C. Cook Nuclear Plant location since 1966, with a full scale pre-operational general ecological survey, covering approximately 98 square miles of southeastern Lake Michigan, in progress since 1972.

The program of studies is designed to provide, prior to plant operation, a number of years of pre-operational data which can subsequently be used to analyze plant impact when compared to data collected after the plant has become operational.

The biological systems examined include the general groups: bacteria, benthic invertebrates, benthic macrophytes, fish, phytoplankton, psammon (animal and diatom), and zooplankton. Techniques and schedules used to study each biological group differ, therefore, a separate discussion is given for each group. The intensity of study effort for component parts of the general ecological survey varies but at no time is the individual effort below levels necessary for valid statistical analysis. A discussion of the statistical procedures can be found in Part XVIII.

It is well recognized that slight change of habitat will be difficult to observe, but because ecological science does not permit exact prediction, it is felt that it is necessary to examine all possible biological effects of plant operation. Therefore, the general ecological survey at the Cook Plant is broad in scope, ambitous in the area of the lake investigated and covers a wide range of biota. While different techniques are used for each study group to detect such changes, most techniques have certain common features, including:

a. Long-term study: the survey period covers several years.

b. Wide study area: about 98 square miles of southeastern Lake Michigan including control and potentially affected areas.

c. Frequent sampling: monthly at selected locations and seasonally at a large number of locations.

d. Multiple sample analysis: in most portions of the study, several samples are either taken or single samples split for replicate analyses.

d. Low level of identification: identifications are made to species level whenever practical.

When considered in concert, these features will enable determination of significant long-term changes in species composition, abundance and species diversity.

WORK PLANS PAST AND PRESENT FOR THE COOK NUCLEAR PLANT SITE SURVEYS

INITIAL PRE-OPERATIONAL STUDIES, 1967-1970

In 1966 when the American Electric Power Service Corporation asked us to undertake the limnological surveys antecedent to the then unnamed Donald C. Cook nuclear electric generating facility, their request was inadvertently a challenge. Prior to that time our only ventures into the shallow nearshore zone had been to make certain physical measurements relative to the earlier establishment of the Big Rock Nuclear Station near Charlevoix, Michigan. The nearshore aquatic environment of southeastern Lake Michigan was completely strange to us. Both physical and biological measurements were requested, and we required a period of time to ascertain that the nearshore zone of southeastern Lake Michigan was a

violent aquatic environment within which there were real problems: 1) could we sample, and 2) how should we sample. Parts I, II, IV, and VII of our report series reflect our progress in becoming physically and biologically familiar with the region.

Our work during this period consisted of the collection and analyses of physical and biological data, modification of techniques, and determination of problems (primarily biological) that were characteristic of this particular nearshore region. Physically, the region demanded unexpected strengthening and stronger anchoring of physical instruments; biologically, the region presented 1) the potentialities of advected water quality influences from the damaged southern end of the lake and from the damaged St. Joseph River to the north, 2) a more-than-probable difference between inshore and offshore biotic populations, and 3) a population of local shore residents who were acutely aware of conditions of nearshore water qualities (principally visible) in the water in which they swam. These biological questions posed by the Cook Plant area became the initial criteria upon which the second stage of the biological pre-operational studies were based.

SECOND STAGE PRE-OPERATIONAL STUDIES, 1970-1972

In the development of the grid of sampling stations for the second stage studies, additional criteria were also considered. In this context we quote from pages 66-68 of Part IV of our report series where the criteria are specifically addressed.

"Six substantial considerations have influenced the development of the sampling system at the stations around the Cook plant site.

First, the system must representatively sample the aquatic and biotic parameters of the environment. "Representatively" here contains the concept of providing adequate coverage, giving a reasonable economy of sampling time and sample work-up, and be navigationally practical.

Third, currents from the south can bring toward the site water containing higher nutrients from an unknown source. A part of the sampling-station system must, therefore, be located well to the south of the site where the Cook thermal plume would never reach. Similarly, currents from the north will bring toward the site water of damaged quality from the polluted St. Joseph River, necessitating that a part of the sampling system be well to the north beyond reach of the Cook plume. These more remote parts of the system are designed to monitor pollution-caused changes that might wrongly be attributed to effects produced by the Cook plant.

Fourth, a wave-washed zone practically devoid of benthos exists close along the shore. Since both the intake and outfall for the Cook Plant will be situated in this "sterile zone," and since this zone will experience the greatest effect of the Cook plume, the shoreward sampling stations must accurately depict and adequately sample this zone both in the pre-operation and post-operation periods. The most lakeward parts of the sampling system should lie outside the reach of the Cook plume.

Fifth, the currents which will receive the plant plume are predominantly alongshore currents to the north or to the south. The system of sampling stations must therefore provide for adequate sampling of the plume as it moves north or south along the beach. The north-south station arrangements must also include stations close inshore where the cottagers may observe, or claim to observe, blooms of algae that they attribute to Cook Plant's waste heat.

Sixth, the system should contain the maximum number of stations at depths which are comparable. On the quite-uniformly sloping bottom off the Cook Plant, depth is fairly equatable to distance from shore. Except for two most landward rows of sampling stations (at 15 and 30 feet of depth), comparability of depth is taken to be achieved by equal distances from the beach.

From a consideration of all the above points, the system of sampling illustrated in Figure 27 (Figure 1) evolved.

Because the Cook Plant area is devoid of charted landmarks sufficient to enable the use of sextant fixes, it will be necessary to navigate by radar ranges and bearings. Although the sampling station system is designed to produce an arc with a radius of seven-miles around the outfall of the Cook Plant, it is practical to occupy the sampling stations only on courses perpendicular to shore where radar distances to shore and to the St. Joseph pierheads can be used as the primary fix. The radar azimuths to both locations, however, may be used as back-up fixes. We believe that the sampling system proposed meets as well as possible the fundamental design-of-experiments concepts that must be met; we know it meets as well as possible the practical navigational problems; and we think it meets the requirement of concentrating data in critical areas. We will not hesitate to modify it if we acquire evidence that something else is better, but we consider this to be presently the best possible arrangement of sampling stations around the Cook Plant."

During the second stage studies emphasis was upon the phytoplankton which, as the first step in the food web, live among and upon the chemical and physical attributes of the environment, and could be expected to be the most sensitive

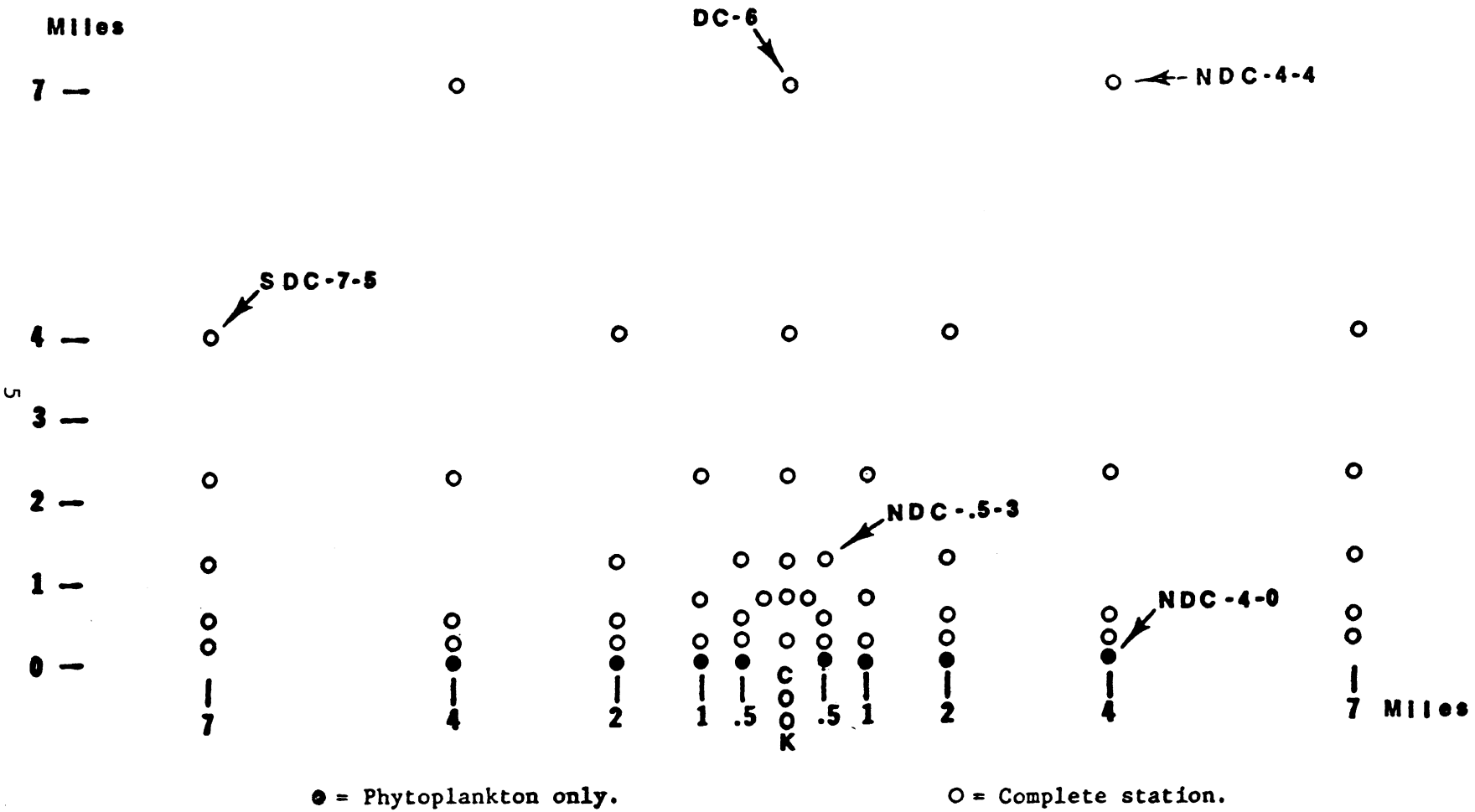

Figure 1. Second stage sampling stations. The stations are designated as follows: SDC stations are located south of the Donald Cook Plant, NDC stations are north of the plant, and the DC stations are directly offshore. The first number in the designation is the number of miles north or south of the plant. The second number is the serial number of the station. The serial number of the phytoplankton-only stations is 0.

indicators of environmental change. Our primary concern among the phytoplankton was the preparation of massive species lists with accompanying cell counts which allowed us to watch over time for species appearances or disappearances, changes in population proportions, or changes in diversity indices.

During this stage emphasis in the zooplankton and benthos was on numbers by supraspecific groups but, as expertise in these areas was added to our staff, it became possible to develop species lists.

Surveys during the second stage studies were on a seasonal basis; the procedures used, and the types of results obtained, are presented in Part IX of our report series. As results from summer 1970 (Part IX) to fall 1970 (Part XV) were worked up, it became evident that sampling by seasons would not provide sufficient understanding of pre-operational phytoplanktonic behavior in the Cook Plant area. This was also borne out by results obtained from studies by Dr. Eugene F. Stoermer who carried out monthly studies of the planktonic algal quality of the southern third of Lake Michigan during the navigational season of 1971,1972 and 1973. Two of Dr. Stoermer's stations are in our grid for the Cook Plant surveys and provided an adventitious source of information between our seasonal surveys.

In April 1972 the last of our second stage surveys of the Cook Plant area was carried out on the sampling grid of Figure 1 and by the methods detailed in Part IX of the report series.

In May 1972 we began a transition to our final plan for pre-operational and post-operational surveys relative to the Cook Plant. The first change was to add monthly coverage of a reduced number of stations of the survey grid.

THE FINAL PRE-OPERATIONAL STUDY PLAN, 1972-1973

Short or Monthly Surveys. Beginning in May 1972, a short survey grid has been sampled in every month from April through November when a seasonal survey was not taken The short survey station grid used in these samplings is shown in Fig. 2. Designed to

provide temporal continuity in the biological collections during the intervals between seasonal surveys, the short grid has been sampled in May, June, August, September, and in November and December if weather conditions permitted.

The stations comprising the short grid were: the six stations of the DC line directly off the plant site (Stations DC-1 through DC-6) plus an additional station (DC-0) in the surf zone in front of the plant; also included are stations NDC-.5-1 and SDC-.5-1. The latter two stations, along with DC-1, provide a small concentration in the region of the plant intakes and outfalls. NDC-7-5 and SDC-7-5 were added in 1973 as controls.

Monthly surveys of the short grid include coliform bacteria, phytoplankton, zooplankton, and triplicate benthos samples, essentially by the methods previously reported in Part IX. Other monthly samplings which do not involve the station grid are periphyton collections, animal and diatom psammon collections, and fish collections.

Major or Seasonal Surveys. Beginning in April 1972 seasonal surveys of a 36-station sampling grid were put into effect. The intended months for spring, summer and fall sampling of this grid are April, July, and October. The grid of stations for the seasonal samplings is shown in Figure 3. This grid was derived by omission of stations from the larger grid used in the second stage pre-operational studies (Fig. 1).

The 36-station grid was tested for effecacy by cross-comparing phytoplankton parameters from the old 54-station grid with the grid represented by 36 of its stations. Parameters compared were: number of organisms/ml, number of species or groups, range of diversity index, average diversity index, average number of organisms/ml, average number of groups or species, class mark of the mode of numbers/ml. the median of numbers/ml. and the numerically dominant

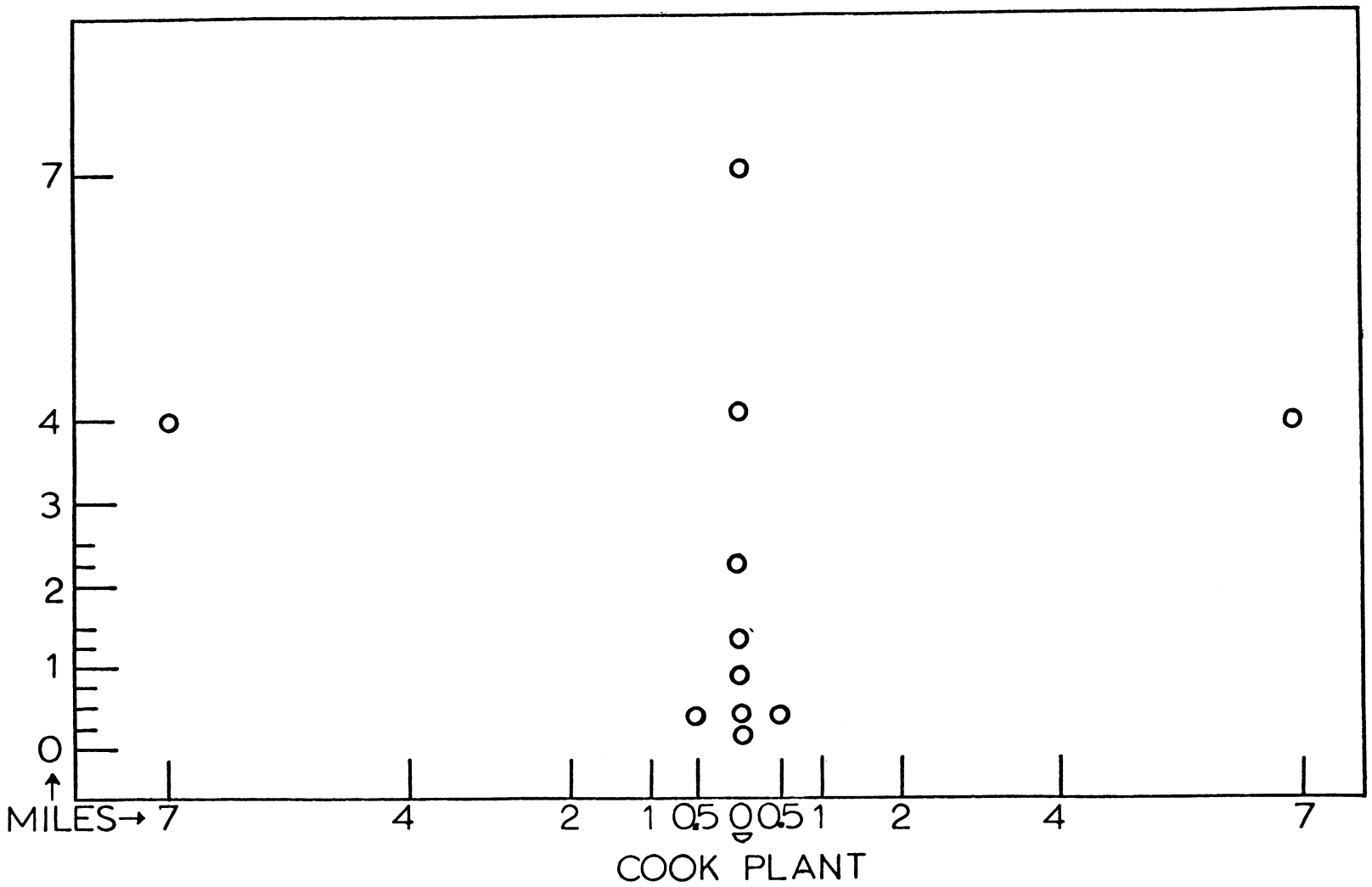

Figure 2. Short or monthly survey station grid. NDC-7-5 and SDC-7-5 were added in 1973.

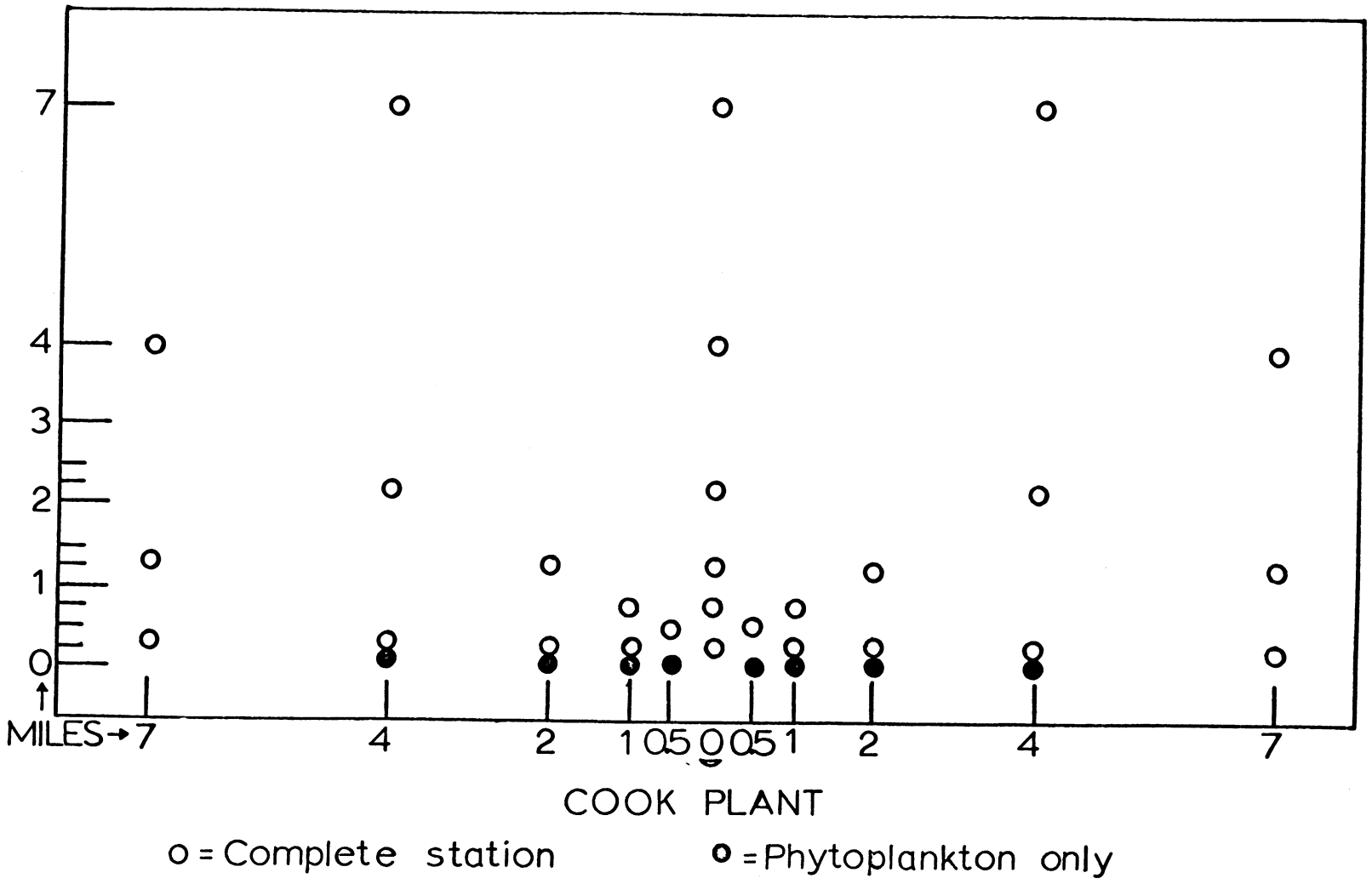

Figure 3. Major or seasonal survey station grid.

organism. The small differences between the two sets of results were found to be insignificant.

In both the short grid and the 36-station major grid the stations have retained their original numbers from the 54-station grid, in order that comparability over time be preserved. The 36 stations are listed in Table 1.

TABLE 1. The sampling stations, their positions relative to the Cook Plant, their distances offshore, and the water depths encountered on 10 July 1970.

Station	Position Relative to the Cook Plant	Water depth (ft) July 1970
DC-1	Directly off the plant, 1/4 mi offshore	19
DC-2	" " " " 3/4 " "	40.5
DC-3	" " " " 1 1/4 " "	56.5
DC-4	" " " " 2 1/4 " "	65.5
DC-5	" " " " 4 " "	79.5
DC-6	" " " " 7 " "	130.5
NDC-.5-2	1/2 mi north of the plant, 1/2 mi offshore	26.5
NDC-1-1	1 " " " " " 1/4 " "	18.5
NDC-1-2	" " " " " " 3/4 " "	33.5
NDC-2-1	2 " " " " " 1/4 " "	18.5
NDC-2-3	" " " " " " 1 1/4 " "	51
NDC-4-1	4 " " " " " 1/4 " "	17.5
NDC-4-3	" " " " " " 2 1/4 " "	55.5
NDC-4-4	" " " " " " 7 " "	134.5
NDC-7-1	7 " " " " " 1/4 " "	22
NDC-7-3	" " " " " " 1 1/4 " "	48
NDC-7-5	" " " " " " 4 " "	71.5
SDC-.5-2	1/2 " south " " " 1/2 " "	28.5
SDC-1-1	1 " " " " " 1/4 " "	13.5
SDC-1-2	" " " " " " 3/4 " "	40
SDC-2-1	2 " " " " " 1/4 " "	18
SDC-2-3	" " " " " " 1 1/4 " "	51.5
SDC-4-1	4 " " " " " 1/4 " "	14
SDC-4-3	" " " " " " 2 1/4 " "	59.5
SDC-4-4	" " " " " " 7	102.5
SDC-7-1	7 " " " " " 1/4 " "	14
SDC-7-3	" " " " " " 1 1/4 " "	51.5
SDC-7-5	" " " " " " 4 " "	70.5

continued---

TABLE 1 continued. Additional stations for phytoplankton only. (All in 4 ft of water.)

Station	Position Relative to the Cook Plant
NDC-.5-0	1/2 mi north of the plant, just off the beach
NDC-1-0	1 " " " " " " " " "
NDC-2-0	2 " " " " " " " " "
NDC-4-0	4 " " " " " " " " "
SDC-.5-0	1/2 " south " " " " " " "
SDC-1-0	1 " " " " " " " " "
SDC-2-0	2 " " " " " " " " "
SDC-4-0	4 " " " " " " " " "

THE ENVIRONMENTAL MONITORING PROGRAM

This section has two purposes: first to indicate the sampling intensity and the location of the samples; and second to illustrate the procedures employed in the collection of the samples and in the analysis of the samples. To achieve this aim the section has been divided into two parts. The first part presents the sampling program being carried out and incorporates the sampling program envisioned for the coming years. In this manner it provides the reader an overview of the entire program in a relatively few number of pages yet in concise terms. The second part on the other hand, gives in some detail the descriptions of the sampling procedures employed for each group of organisms. Included there are both the field sampling procedures and the techniques employed in working up the samples once they are in the laboratory.

FIELD SAMPLING SCHEDULES FOR BIOTA

The sampling schedules for each group are presented in tabular and figure form. The months and stations used for the general ecological survey in the vicinity of the plant are given in Table 2. All elements of the biota investigated are presented with the exception of the entrainment and impingement studies which are dealt with separately. For easy reference to the identification of the stations used in Table 2 the reader is provided Table 3 showing the transects and distances of these stations from shore and north and south of the plant site.

Since as noted earlier this program is a long term study the total number of field samples anticipated for each year 1973-1978 in six categories is presented as a summary in Table 4. To provide a comparison of the biological field sampling schedule used in 1973 with that of the field sampling during the combined field and entrainment years and subsequent field years without entrain-

ment Table 5 is included. The program in these tables is naturally dependent on the startup dates of Units I and II and assumptions made to that effect in arriving at these schedules should be noted when reading these tables. In the period of 1973-1978 there will be three years of full scale field study and three years of studying where field and entrainment studies are combined. The tables and figures presented in this section provide the field sampling schedules. For the entrainment and impingement programs, a very important part of the overall program, the reader is referred to the second part of this section.

TABLE 2

MONTHS AND STATIONS USED FOR GENERAL ECOLOGICAL SURVEY
(see Table 3 for transect locations and distances from shore)

Zooplankton

(A) 1973

Short surveys: 5 months (May, June, August, September, November)
10 stations (as shown below, see Figure 4).

DC-1	DC-2	DC-3	DC-4	DC-5	DC-6
NDC-.5-2		NDC-7-5			
SDC-.5-2		SDC-7-5			

Major surveys: 3 months (April, July, October)
28 stations (as shown below, see Figure 5).

DC-1	DC-2	DC-3	DC-4	DC-5	DC-6

NDC-.5-2				SDC-.5-2		
NDC-1-1	NDC-1-2			SDC-1-1	SDC-1-2	
NDC-2-1	NDC-2-3			SDC-2-1	SDC-2-3	
NDC-4-1	NDC-4-3	NDC-4-4		SDC-4-1	SDC-4-3	SDC-4-4
NDC-7-1	NDC-7-3	NDC-7-5		SDC-7-1	SDC-7-3	SDC-7-5

(B) Years With Concurrent Entrainment and Impingement Studies

Short surveys: 5 months (May, June, August, September, November)
10 stations (as shown below)

DC-1	DC-2	DC-3	DC-4	DC-5	DC-6
NDC-.5-2		SDC-.5-2		NDC-7-5	SDC-7-5

Major surveys: Same as for (A)

(C) Years Without Concurrent Entrainment and Impingement Studies

Short surveys: Same as for (B)

Major surveys: Same as for (A)

Phytoplankton

(A) 1973

Short surveys: 5 months (May, June, August, September, November)
11 stations (as shown below)

DC-0	DC-1	DC-2	DC-3	DC-4	DC-5	DC-6
NDC-.5-2		SDC-.5-2		NDC-7-5		SDC-7-5

Major surveys: 3 months (April, July, October)
36 stations (as shown below)

	DC-1	DC-2	DC-3	DC-4	DC-5	DC-6

NDC.5-0	NDC-.5-2		SDC-.5-0	SDC-.5-2	
NDC-1-0	NDC-1-1	NDC-1-2	SDC-1-0	SDC-1-1	SDC-1-2
NDC-2-0	NDC-2-1	NDC-2-3	SDC-2-0	SDC-2-1	SDC-2-3
NDC-4-0	NDC-4-1	NDC-4-3	SDC-4-0	SDC-4-1	SDC-4-3
	NDC-4-4			SDC-4-4	
NDC-7-1	NDC-7-3	NDC-7-5	SDC-7-1	SDC-7-3	SDC-7-5

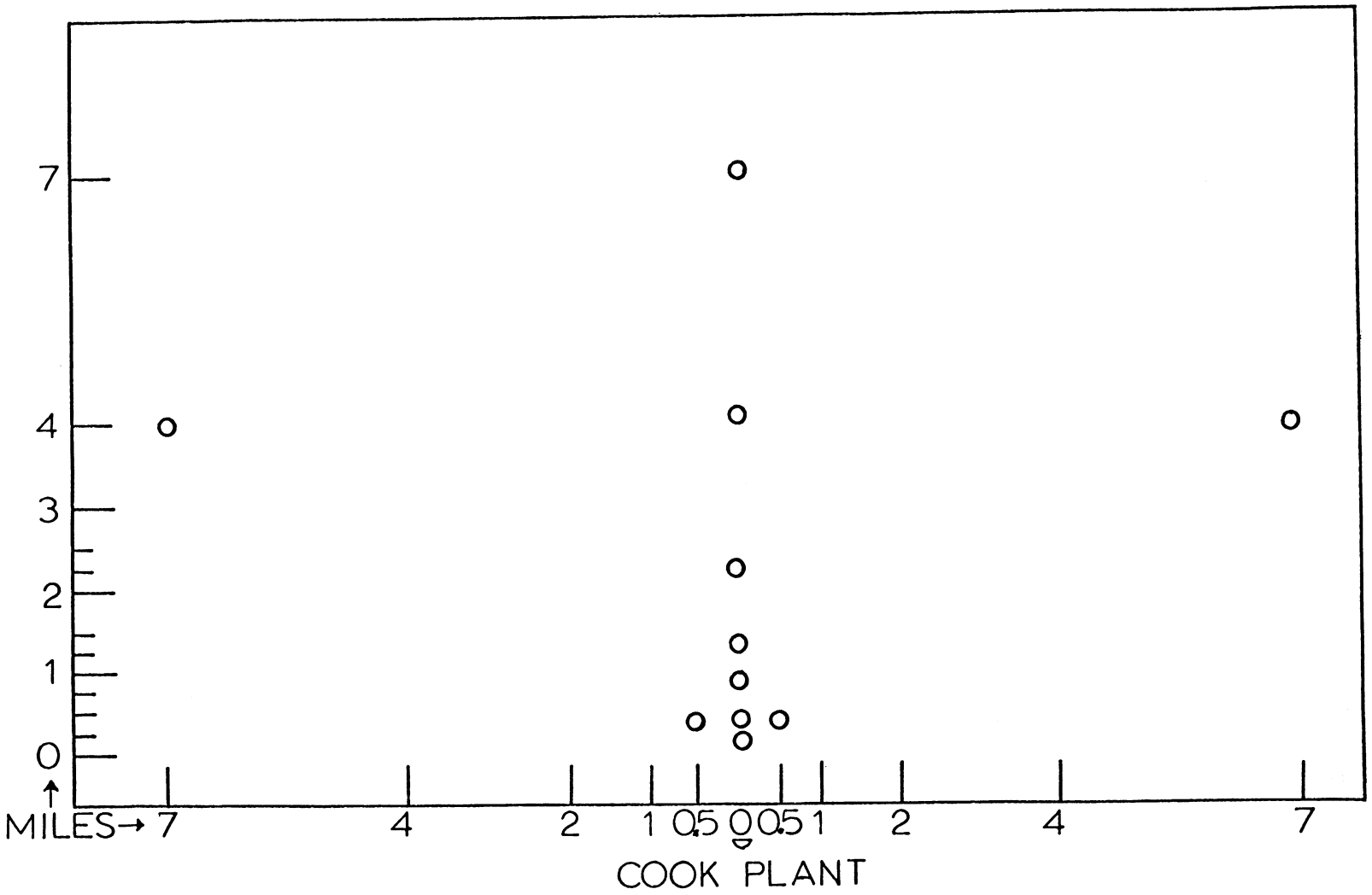

Figure 4. Short or monthly survey station grid.

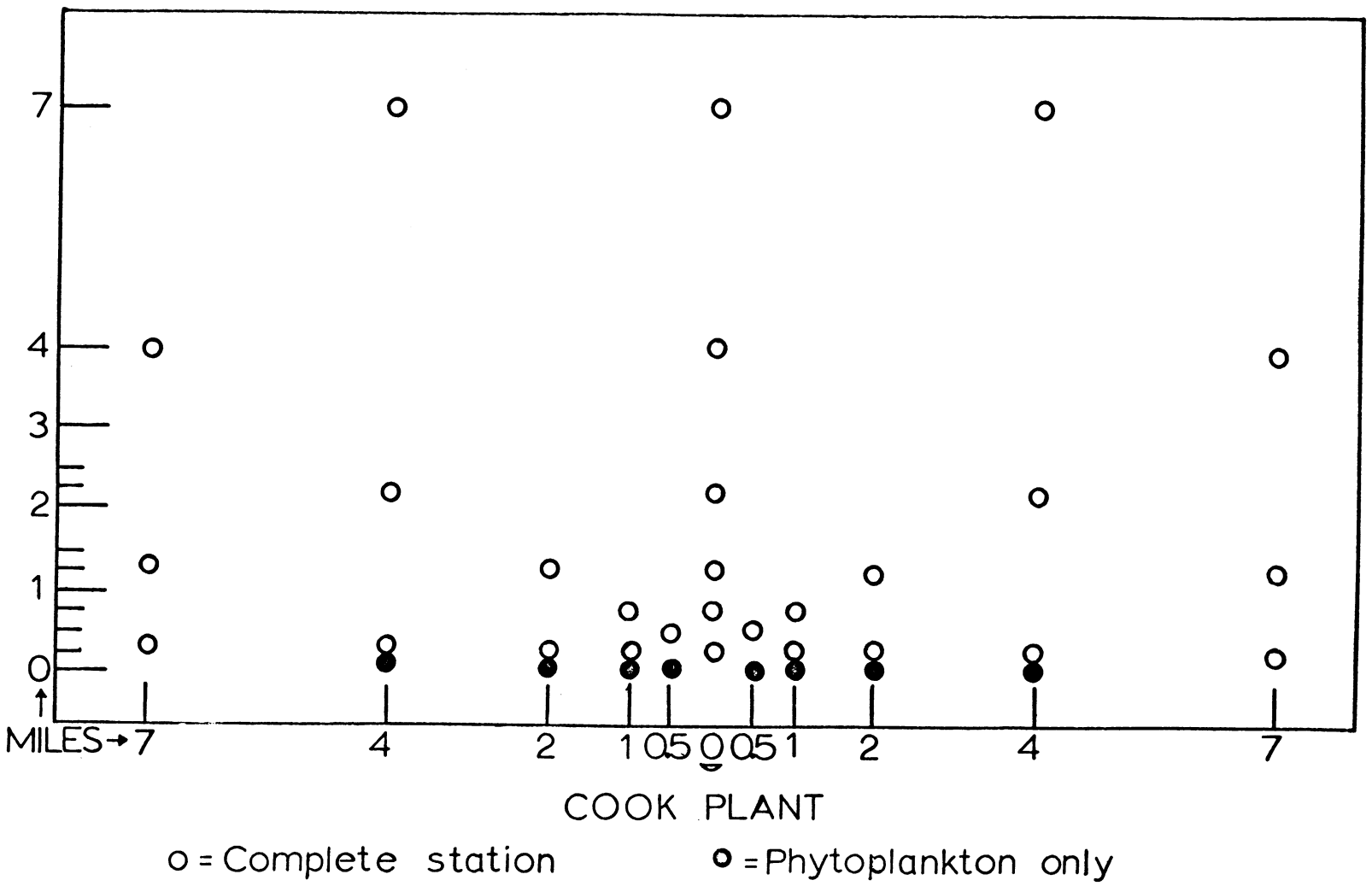

Figure 5. Major or seasonal survey station grid.

TABLE 2 (Continued)

MONTHS AND STATIONS USED FOR GENERAL ECOLOGICAL SURVEY
(see Table 3 for transect locations and distances from shore)

(B) Years With Concurrent Entrainment and Impingement Studies

Same as for (A)

(C) Years Without Concurrent Entrainment and Impingement Studies

Same as for (A)

Benthos

Benthos stations for 1973 were described Part XIII of our report series, pp. 214-218*. Beginning in 1974 stations will be the same as those shown for zooplankton on the preceding page. Each sample will be the contents of chamber #1 of a triplex Ponar grab. The months of collection of both short and major surveys are the same as those shown for zooplankton in 1973. The 3 replicates at a station will be from 3 casts of the grab, not the 3 chambers of a single cast.

Periphyton

Months: 7 (May, June, July, August, September, October, November)

Periphyton stations are located along the north and south range poles 1/4 mile N and S of the plant in water depth of 15 and 30 feet.

Psammon

Months: 7 (April, May, June, July, August, September, October)

Three sites are sampled: the first (DC) is approximately 200 m north of the Donald C. Cook Plant, the second (NDC) about three miles north of the plant, and the third (SDC) at the southern end of Warren Dunes State Park (about five miles south of the plant).

Bacteria

Short surveys: 5 months (May, June, August, September, November)
8 stations (as shown below)

DC-1 DC-2 DC-3 DC-4 DC-5 DC-6
NDC-.5-2 SDC-.5-2

*Benton Harbor Power Plant Limnological Studies. Part XIII. Cook Plant Preoperational Studies 1972. 281 pages. March 1973.

TABLE 2 (Continued)

MONTHS AND STATIONS USED FOR GENERAL ECOLOGICAL SURVEY
(see Table 3 for transect locations and distances from shore)

Major surveys: 3 months (April, July, October)
22 stations (as shown below)

DC-1	DC-2	DC-3	DC-4	DC-5	DC-6
NDC-.5-2				SDC-.5-2	
NDC-1-2				SDC-1-2	
NDC-2-3				SDC-2-3	
NDC-4-1	NDC-4-3			SDC-4-1	SDC-4-3
NDC-7-1	NDC-7-3	NDC-7-5		SDC-7-1	SDC-7-3	SDC-7-5

Beginning in 1977, short surveys for bacteria will be conducted during all 8 months, April through November.

Aquatic Macrophyte

Months: Usually October or November

Stations:

Transect 1. In water depth of 20 feet in line with the North Range Pole to a depth of 50 feet.
Transect 2. 1300 feet south of transect 1 starting at the depth of 50 feet and continues shoreward to a depth of 15 feet.
Transect 3. Starts at a depth of 18 feet and continues offshore directly in line with the South Range Pole to a depth of 50 feet.
Transect 4. 1300 feet north of transect 3 starting at a depth of 50 feet and proceeds shoreward to a depth of 15 feet.

The transects are shown in Figure 6.

Fish

Months: 8 (April through November)

Seven permanent stations were established in the area of the plant and Warren Dunes State Park (control site). Two seining stations (A and B) north and south of the plant and two gillnetting stations and trawling stations (C and D) in 20 and 30 feet of water in the vicinity of the plant. (The fishing areas at the plant are shown in Figure 7.)

At Warren Dunes State Park (control location) one seining station (F) and two stations (G and H) in water depth of 20 and 30 feet of water are used for gillnetting and trawling. Fish larvae tows are conducted at all seven stations.

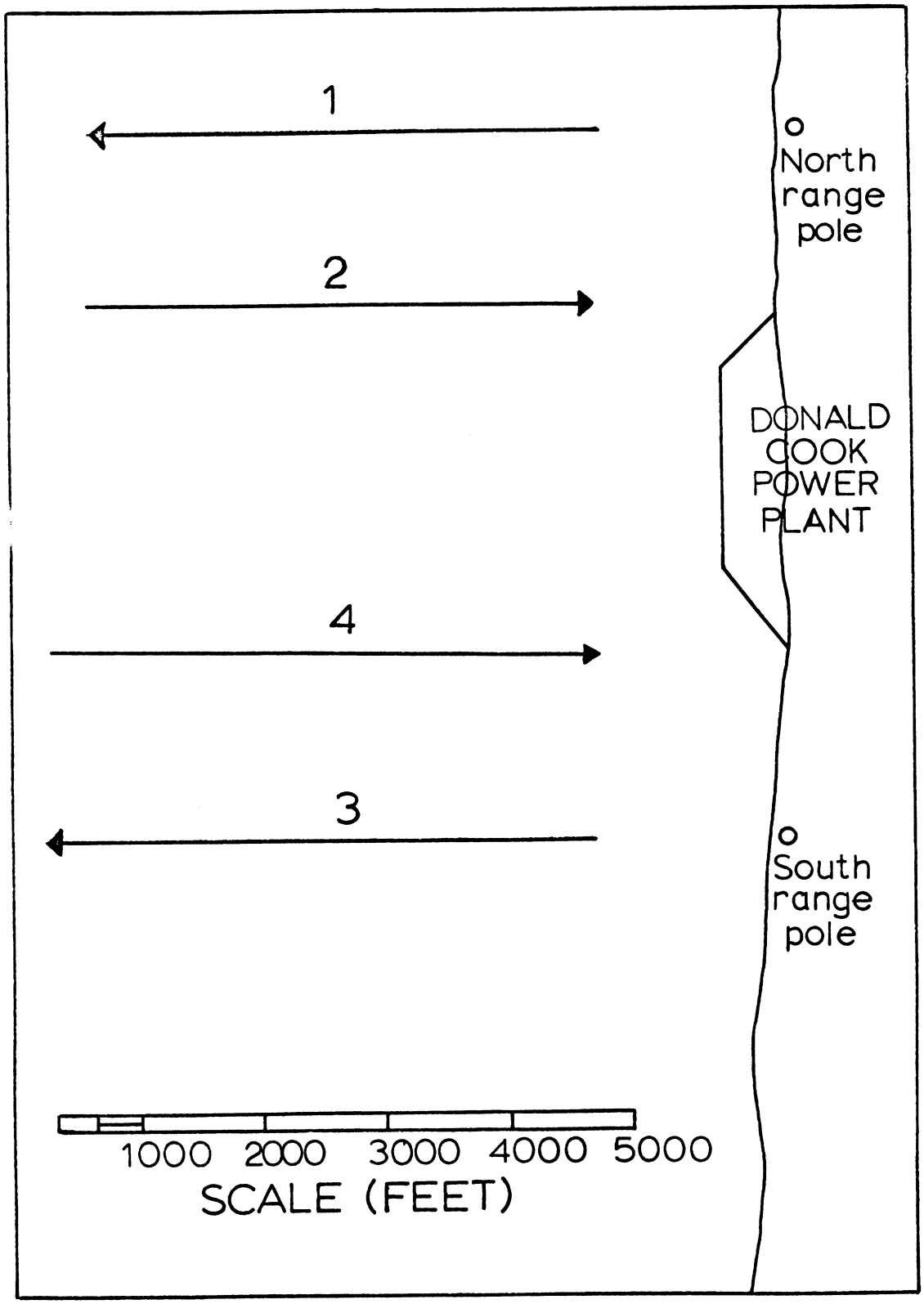

Figure 6. Location of transects for macrophyte survey.

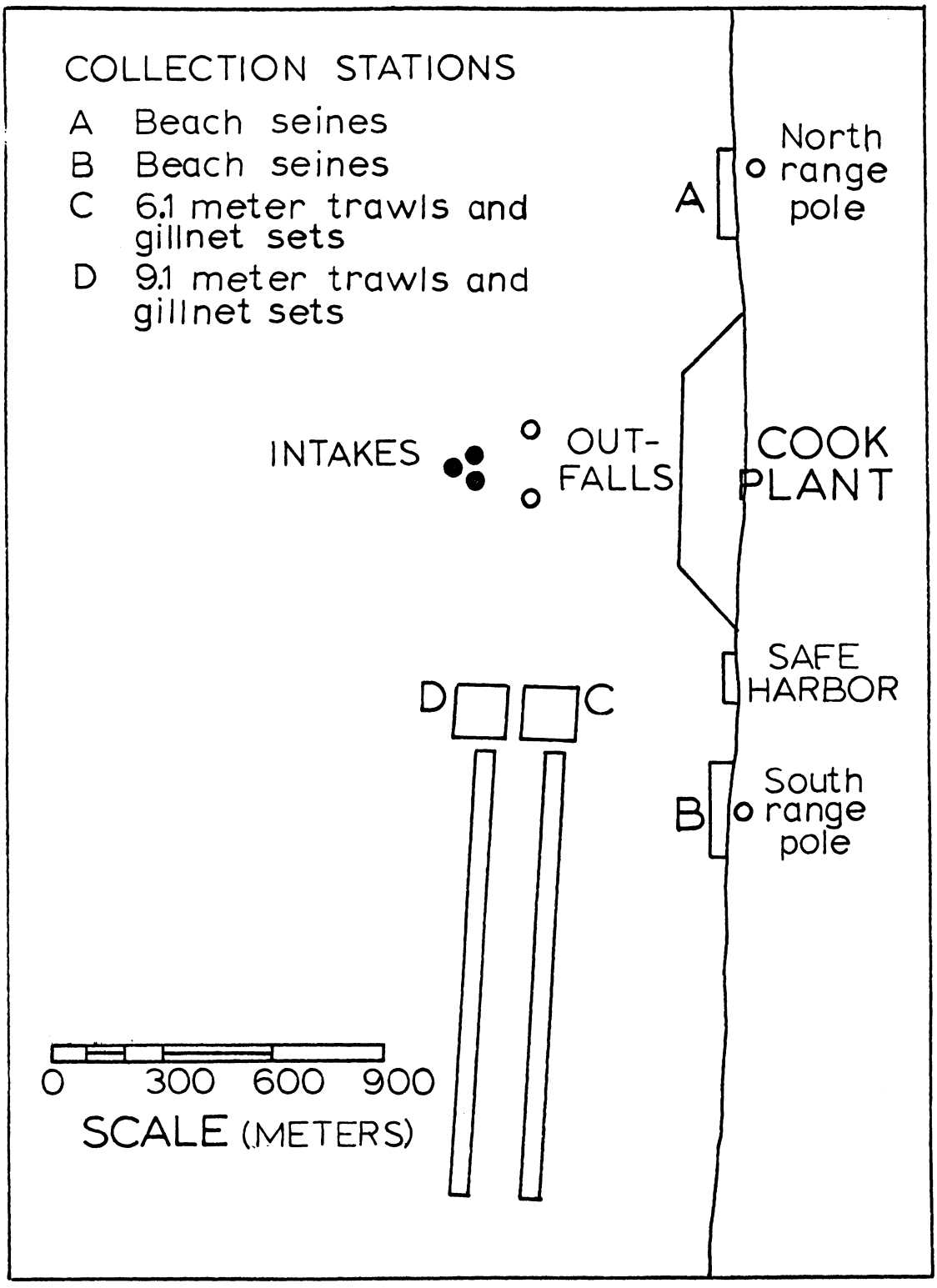

Figure 7. Map of the area showing locations of the Cook Plant, intake and discharge structures, and seining (A,B), gillnetting and trawling (C,D) stations. Seining station (F) and gillnetting and trawling stations (G and H) at Warren Dunes State Park (Control location) are not shown.

TABLE 3

The DC, NDC and SDC Stations: A Table Showing their Transects and Distances from Shore

This table includes 54 stations, 18 of which are no longer used for major surveys. The stations that will be used for zooplankton, phytoplankton and benthos in 1974 are among those listed here. Periphyton, psammon and fish are collected at specialized stations that are not included here. Stations whose names end in 0, like NDC-1-0, are in the surf. They are used only for phytoplankton collections.

Entries in the 'Transect' columns are interpreted as follows. Stations in the row marked '0.00' are on the DC transect, which leaves shore right at the plant (41° 58.5' N, 86° 34.0' E) and runs in a west-northwesterly direction with bearing 290°. The other transects are parallel to this one; their distances from it are indicated in the 'Transect' columns in both miles and kilometers. Positive distances refer to transects north of the plant; negative distances refer to transects south of the plant. The distance of each station from shore is measured along the transect and is given here in both miles and kilometers. Metric distances have been rounded to the nearest multiple of 0.40 km.

* Stations marked with an asterisk have not been used in major surveys since May 1, 1972.

Transect		Distance of each station from shore (km, and miles)									
		0.00	0.40	0.80	1.20	1.60	2.00	3.60	6.40	11.20	(km.)
km.	mi.	0.00	0.25	0.50	0.75	1.00	1.25	2.25	4.00	7.00	(mi.)
-11.20	-7.00		SDC-7-1	SDC-7-2*			SDC-7-3	SDC-7-4*	SDC-7-5		
-6.40	-4.00	SDC-4-0	SDC-4-1	SDC-4-2*				SDC-4-3		SDC-4-4	
-3.20	-2.00	SDC-2-0	SDC-2-1	SDC-2-2*			SDC-2-3		SDC-2-4*		
-1.60	-1.00	SDC-1-0	SDC-1-1		SDC-1-2			SDC-1-3*			
-0.80	-0.50	SDC-.5-0	SDC-.5-1*	SDC-.5-2			SDC-.5-3*				
-0.40	-0.25				SDC-.25-1*						
0.00	0.00		DC-1		DC-2		DC-3	DC-4	DC-5	DC-6	
0.40	0.25				NDC-.25-1*						
0.80	0.50	NDC-.5-0	NDC-.5-1*	NDC-.5-2			NDC-.5-3*				
1.60	1.00	NDC-1-0	NDC-1-1		NDC-1-2			NDC-1-3*			

TABLE 3 (Continued)

The DC, NDC and SDC Stations: A Table Showing their Transects and Distances from Shore

Transect		Distance of each station from shore (km, and miles)									
		0.00	0.40	0.80	1.20	1.60	2.00	3.60	6.40	11.20	(km.)
km.	mi.	0.00	0.25	0.50	0.75	1.00	1.25	2.25	4.00	7.00	(mi.)
3.20	2.00	NDC-2-0	NDC-2-1	NDC-2-2*			NDC-2-3		NDC-2-4*		
6.40	4.00	NDC-4-0	NDC-4-1	NDC-4-2*				NDC-4-3		NDC-4-4	
11.20	7.00		NDC-7-1	NDC-7-2*			NDC-7-3	NDC-7-4*	NDC-7-5		

TABLE 4

Total Number of Field Samples for each Year
1973-1978, in Six Categories

(Entrainment sampling is not included)

For ease of comparison, this table assumes startup of Unit I on Jan. 1, 1975 and of Unit II on Jan. 1, 1976. In any case, the entrainment studies will run during all of 1974, to study mechanical damage, and for 12 months after the startup of each unit. Field sampling will be reduced as shown below during each 12-month period of entrainment study. The field program will continue for 36 months after Unit II begins operation. For an explanation of the totals given below, see Table 5.

	Number of samples in each year					
Year	Zoopl.	Phytopl.	Benthos	Periphyton	Psammon	Bacteria
1973	402	163	558	28	126	106
1974*	218	163	252	0	0	0
1975*	218	163	252	#	#	#
1976*	218	163	252	#	#	#
1977	402	163	372	28	84	128
1978	402	163	372	28	84	128

A yet to be determined number of samples.

* Entrainment study year.

TABLE 5

Comparison of the Biological Field Sampling Schedule Used in 1973 with the Schedules Planned for 1974 and 1977

Zooplankton

1973	short surveys:	5 mos x 10 stns x 3 reps =	150
	major surveys:	3 mos x 28 stns x 3 reps =	252
		Total	402 samples
1974	short surveys:	5 mos x 10 stns x 1 rep =	50
	major surveys:	3 mos x 28 stns x 2 reps =	168
		Total	218 samples
1977	short surveys:	5 mos x 10 stns x 3 reps =	150
	major surveys:	3 mos x 28 stns x 3 reps =	252
		Total	402 samples

Phytoplankton

1973	short surveys:	5 mos x 11 stns x 1 rep =	55
	major surveys:	3 mos x 36 stns x 1 rep =	108
		Total	163 samples

1974 and 1977 same as for 1973

Benthos

In the 1973 survey the number of replicates per station was not the same in all zones. For details, see pp. 214-218 of Part XIII of our report series.

1973	short surveys:	5 mos x 36 samples =	180
	major surveys:	3 mos x 126 samples =	378
		Total	558 samples
1974	short surveys:	NONE =	0
	major surveys:	3 mos x 28 stns x 3 reps =	252
		Total	252 samples
1977	short surveys:	5 mos x 8 stns x 3 reps =	120
	major surveys:	3 mos x 28 stns x 3 reps =	252
		Total	372 samples

TABLE 5 (cont.)

Periphyton

1973 7 mos x 2 transects x 2 depths = 28 samples

1974 NONE

1977 Same as in 1973.

Psammon

1973 7 mos x 3 sites x 3 elevations x 2 reps = 126 samples

1974 NONE

1977 7 mos x 3 sites x 2 elevations x 2 reps = 84 samples
(The waterline samples will be discontinued)

Bacteria

1973 short surveys: 5 mos x 8 stns x 1 rep = 40
major surveys: 3 mos x 22 stns x 1 rep = 66

Total 106 samples

1974 NONE

1977 short surveys: 8 mos x 8 stns x 2 reps = 128
major surveys: NONE 0

Total 128 samples

Sampling and laboratory methods

The intent of this section of the report is to outline the procedures that are employed in the collection of samples and to describe the procedures used in the handling of the samples both in the field and in the laboratory.

This section of the report complements the discussion of the field sampling schedules for biota and combined with it makes a complete discussion of the program. Where it was thought useful figures have been repeated for ease of reference and to permit the reader to visualize aspects of the program readily.

This section is also split into two parts that are identified by two subsections: regular field studies and impingement and entrainment studies.

Each part is dealt with individually as is each element of the biota studied.

Zooplankton

Field method. Three replicate zooplankton samples are collected at each of the 28 complete stations in the 3 major seasonal surveys (Figure 8), and at each of the short monthly survey stations, (Figure 9) less DC-0. At each station, a vertical haul from the bottom to the surface is made with a 1/2 meter cone net of #10 nylon mesh (158μ apertures). This mesh size retains all adult cladocerans and copepods (including small species such as *Tropocyclops prasinus*), but probably does not quantitatively recover small nauplii or small rotifers. A flowmeter placed in the mouth of the net estimates the volume of water filtered. About 1 to 10 m^3 of water are filtered depending on the length of the tow. Samples are preserved with Koechie's Fluid (a mixture of 750 ml saturated sugar solution, 300 ml concentrated formalin, and 2850 ml distilled

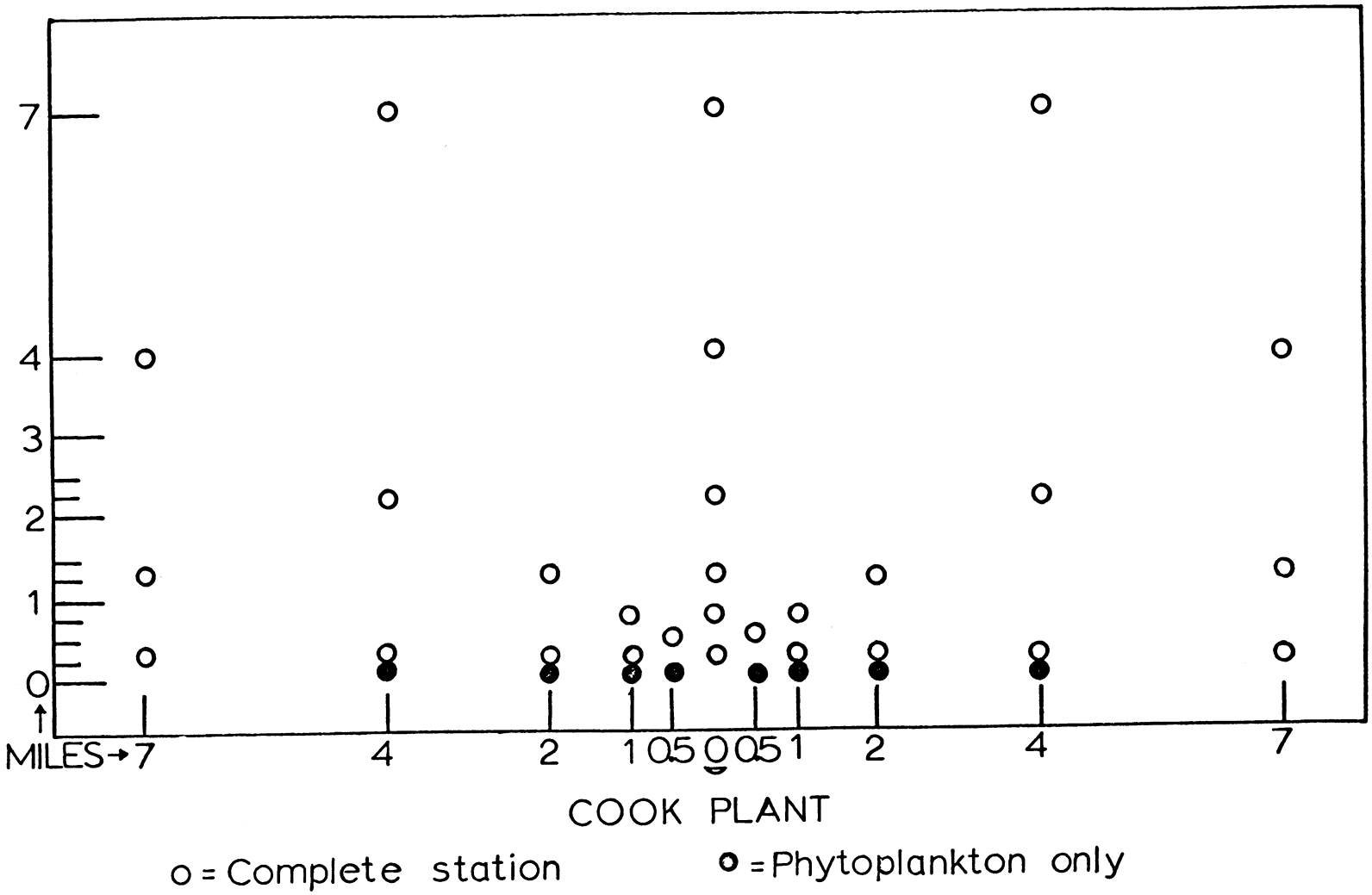

Figure 8. Major or seasonal survey station grid.

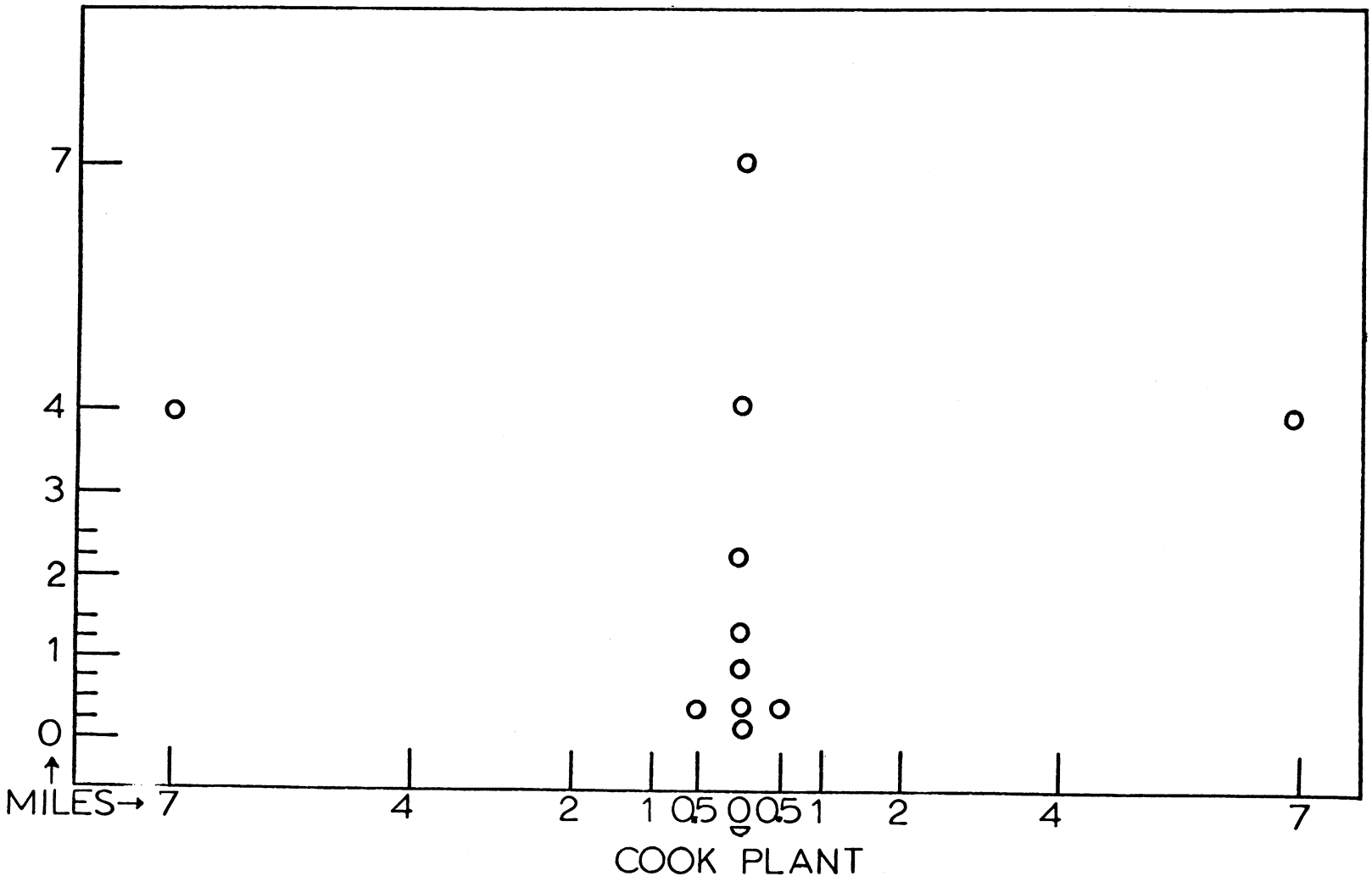

Figure 9. Short or monthly survey station grid.

water), which is used rather than formalin to further minimize distortion of the microcrustacea, in particular "ballooning" of cladoceran carapaces.

Laboratory method. The collected samples are subsampled in the laboratory with a Folsom plankton splitter, each sample is split as many times as necessary to yield a subsample of manageable size which still permits statistical reliability. At each split the half which is used for further splits or for counting is chosen at random by tossing a coin. Duplicate subsamples for counting are selected, each of which contains several hundred of the most common forms. Larger subsamples are examined for rarer forms. Subsamples are counted in a chamber of original design which combines the features of Gannon's chambered cell and Ward's plankton wheel. Stereozoom microscopes capable of magnification up to 210 X are used. This, combined with the open top feature of the chamber (permitting manipulation of specimens into favorable viewing positions), makes it possible to identify species of microcrustacea without dissection. Samples are identified to species at DC2, 5, 6. All other station identification is to genus.

Total zooplankton weights are determined from the counted splits. The zooplankton are weighed on No. 1 Whatman filter papers, 5 cm in diameter, using a Mettler H54 electrobalance (least division equal to 0.1 mg; estimates to 00.01 mg). Before weighing, the filters are dried in an oven at ca. 100°C for at least four hours. Filters are taken from the oven and placed on the balance. The weight is recorded one minute after removal from the oven.

Phytoplankton

Field method. Phytoplankton off of the Cook Plant are sampled monthly from April to November. During three of these months (April, July and October) phytoplankton samples are collected at each of the 36 major survey stations

(Figure 8). During the remaining months, samples are collected from each of the short survey grid stations.

All samples, except from surf zone stations, are collected with a Niskin bottle at a depth of 1 meter, poured into a brown one liter polyethylene bottle and immediately preserved with Lugol's modification of Utermohl's solution. The surf zone stations (4 feet of depth) collected only during full surveys are collected in 1 liter Nalgene bottles at a depth of 6 inches and the same preservation is used. The difference in collection procedure is due to the much shallower depth of water. The fact that the surf zone stations are collected at 6 inches should have little bearing on the correlative results, since the water at these stations is thoroughly mixed.

Laboratory method. The method of concentration for species identification and enumeration is the settle-freeze method as proposed by Sanford et al. (1969). The method entails an overnight settling of 1000 ml of sample in a graduated cylinder. The following day the top 900 ml are siphoned off and discarded. Part of the remaining 100 ml is used for preparation for the microscope slide and the rest is kept for any possible further references or back checking.

The once settled sample is then diluted if need be and settled again, this time in eighteen milliliter cylinders. These cylinders are attached with a small amount of stopcock lubricant (to prevent leakage) to the microscope slides which rest on an aluminum plate one quarter inch thick. The whole apparatus is then secured together mechanically. The microscope slides, prior to having the cylinders placed on them, are treated with Dissicote to provide a hydrophobic surface to the slide. After the samples have settled overnight, the aluminum plate on which they rest is placed on a block of dry ice for ninety seconds. This freezes the bottom one to one and a half milliliters.

The unfrozen part is then discarded and the cylinders are removed from the slides. The slides are then placed in an anhydrous ethanol chamber for three days and then in a toluene chamber for one day.

The first chamber removes the excess water and the second prepares the samples for their final mounting in toluene based Permount. One drop of Permount is put on the slide, a cover slip is then placed over it and the slide is allowed to dry for two days.

The specimens are counted to species when practical, otherwise to genus or group. Only those specimens that appear to have been viable at the time of collection are counted. Two sweeps of the slide are made, one vertical and one horizontal. This provides an indication of the randomness of the species on the slide.

Benthos

Field method*. In 1974 each sample will be the contents of chamber #1 of a triplex Ponar grab. Three hauls will be made at each station. Samples are washed in a funnel-shaped elutriation device which allows rinsing of the animals and lighter sediments over onto a 0.5 mm screen. Residues of sand and coarser materials are discarded. In general, particles and animals larger than 0.5 mm in their least dimension are retained but some smaller animals are also retained, while active and elastic oligochaetes somewhat larger than this occasionally escape. The residue on the screen is washed into a sample bottle and preserved with buffered formalin.

Laboratory method. In the laboratory, samples are sorted under strong light against a black background, usually with magnification. Oligochaeta and

*For 1973 procedure see Part XIII of our report series.

smaller Chironomidae are mounted on slides and identified at high magnification. The age and maturity distribution of *Pontoporeia affinis* are determined for each sample. For each survey, tables are compiled to show the mean abundance for the major taxa (Amphipoda, Oligochaeta, Sphaeriidae, Chironomidae, Total Animals) at each station, for use in Inner/Outer comparisons. Tables and figures are also prepared showing the mean abundance of the more numerous and larger species by depth zones and regions, accompanied by statistical parameters such as the standard deviations and standard errors of the means.

Periphyton

Field method. Four styrofoam periphyton collectors, each bearing duplicate collection surfaces are set, exposed and removed monthly from May through November in water depths of 15 and 30 feet along the north and south range poles (1/4 mi N and S of the plant). The blocks are covered by about one meter of water at the still waterline. One block is used for species identification and the other for average monthly growth determination. The styrofoam collection block used for average monthly growth determination is frozen and returned to the laboratory. Periphyton on the block used for species identification is scraped off the block with a dull knife and placed in a bottle containing preservative (a solution of 6 parts distilled water, 3 parts ethyl alcohol and 1 part formaldehyde).

Laboratory method. For the determination of the apparent average monthly growth the following laboratory technique is employed: the frozen styrofoam blocks are removed from the freezer and the dimensions of all sides are taken. Using a microtome knife, thinly sliced portions of the styrofoam-periphyton are placed into a 100 ml beaker and allowed to sit for about 30 minutes (sufficient time to dry the sample under an air hood). 100 ml of benzene are

added to the sample. Once the styrofoam is dissolved the sample is drawn through a preweighed glass filter separating the styrofoam-benzene solution from the periphyton. The sample in the funnel is rinsed with 200 ml of benzene to assure total removal of the styrofoam and to wash the periphyton from the funnel walls onto the filter. The filter is then air dried and weighed.

The periphyton scrapings are first wet mounted and examined for greens and blue-greens. For species identification the wet mounted scrapings are examined with a Leitz Ortholux Microscope using 156, 313 and 675 X magnification.

Psammon

Animal and Diatom Psammon

Field method. Three sites are sampled April through October: the first ("DC") is located approximately 200 m north of the Donald C. Cook Plant, the second ("NDC") at a small semi-private beach off Grand Mere Road (about three miles north of the plant), and the third ("SDC") at the southern end of Warren Dunes State Park (about five miles south of the plant).

A clear plastic tube with an interior diameter of 4.7 cm is thrust into the sand to a mark indicating a depth of 5 cm. The tube is then carefully removed and stoppered at each end. When vision is hampered by waves, a longer core is taken; the excess sand at the bottom of the core is then pushed out of the tube and sliced off in the field. At each site sets of samples are taken of sediment: from the waterline, from 1 m shoreward of the waterline, and from 1 m lakeward of the waterline. Temperatures of the sediments at each sampling point are read to the nearest 0.5°C from a stem thermometer thrust ca. 5 cm into the sand. Weather conditions and wave height are noted. Sediment samples for grain size determination are collected.

Animal Psammon

Laboratory method. The samples from each site are taken directly to a field laboratory to be washed and preserved. Each sample is placed in a plastic container and flooded with 75-100 ml of water heated to near boiling. This kills the microorganisms in an expanded position. The sand is then stirred vigorously and the water decanted into a pint jar. This washing process is repeated four times. Formalin is then added to the jar, and the samples are labelled and returned to Ann Arbor for examination.

Concentration of the organic material for examination is accomplished by carefully pipetting most of the formalin solution from a sample jar in which the material has had time to settle. The organic material is then washed into a centrifuge tube and either allowed to collect at the bottom or gently centrifuged. We use a fine pipette to remove the material, 1 ml at a time, and place it in a Sedgwick-Rafter cell. An excessive concentration makes it difficult to detect the organisms among the debris, so we examine several 1 ml portions, until the entire sample is processed. All metazoans are identified to the lowest taxonomic level practical and counted under a compound microscope at a magnification of 100 diameters.

Diatom Psammon

Laboratory method. The samples from each site are taken directly to a field laboratory and immediately frozen for return to Ann Arbor. In the laboratory the samples are processed to clean the diatom frustules. The frozen sample is placed into a one-liter beaker and covered by hydrogen peroxide in a volume about equal to the volume of the sample. To speed the reaction a small amount, normally a few crystals, of potassium dichromate are added. The solution will turn dark purple and effervesce. Agitation of the solution in the beaker is necessary for continued reaction. The reaction is

considered complete when the solution no longer effervesces and the color of the solution turns yellow.

To separate the diatom frustules from the sediment, the solution is stirred, resulting in the diatoms remaining in suspension longer than the sediment which settles out rapidly. The diatom frustules are then separated from the sediment by pouring the solution containing the frustules into a smaller beaker. To be certain that all diatoms are removed, the remaining sediment solution is stirred several additional times using distilled water and again pouring the diatom frustules into the smaller beaker. The suspended material in the smaller beaker is then allowed to settle and when the water is clear it is decanted and refilled with distilled water. This procedure is followed until the distilled water loses its yellow tint.

The sample is now ready for mounting on a glass slide. The diatomaceous material is suspended in water, a glass cover slip is covered by the material using a small pipette and the water is allowed to evaporate. The slide is then baked at the 450 setting on a hot plate for 10 minutes. A drop of Hyrax mounting medium is placed on the middle of the slide and the cover slip is inverted on the Hyrax. This slide is now baked until all the toluene solvent in the Hyrax boils out. The slide is then removed from the hot plate, the cover slip is centered and tapped down, and the excess Hyrax is removed from the slide once it has cooled sufficiently. The slide is labelled using a diamond marker as to date and location of the sample.

Bacteria

Field method. Water for total coliform bacteria and phytoplankton analysis is collected simultaneously by Niskin bottle at a depth of 1 meter. Bacteria collections are made monthly at the short survey grid stations

(except DC-0, NDC-7-5 and SDC-7-5). Two hundred fifty ml are drawn into a white translucent polyethylene bottle for each bacteria sample. The samples are refrigerated until each sample can be concentrated in a Millipore Field Monitor.

Millipore Field Monitors are prepackaged sterile membrane filters and absorbent nutrient pads contained in plastic filtering and incubating chambers. In preparing the Monitors duplicates are prepared from each sample, each duplicate receiving a different amount of water, 50 and 25 ml when bacteria are expected to be abundant and 100 and 50 when they are expected to be sparse. Each Monitor is then inoculated on the absorbent pad with an ampoule of Millipore M-Endo Broth, sealed, and incubated at 35°C $\pm$ 1°C for 18-24 hours.

After incubation the Monitors are opened, the filters carrying the bacteria removed, and preserved by drying. Dried filters are returned to the laboratory for counting.

Laboratory method. Filters are counted with a low-magnification binocular dissecting microscope with overhead illumination. Counts of the greenish metallic "sheen" coliform colonies are converted to bacteria per 100 ml by: number of sheen colonies/number ml of sample x 100.

Aquatic Macrophytes

An underwater study of macrophyton (rooted aquatic plants) is conducted in October of each year. Using a diver and support vessel, the lake bottom in the general vicinity of the Cook Plant is observed. The survey follows the pattern shown in Figure 10.

The survey starts north of the plant with transect 1 and continues along transect 1 from a depth of 20 feet to 50 feet. Transect 2 starts at the depth of 50 feet and continues shoreward to a depth of 15 feet. Transect 2 is 1300

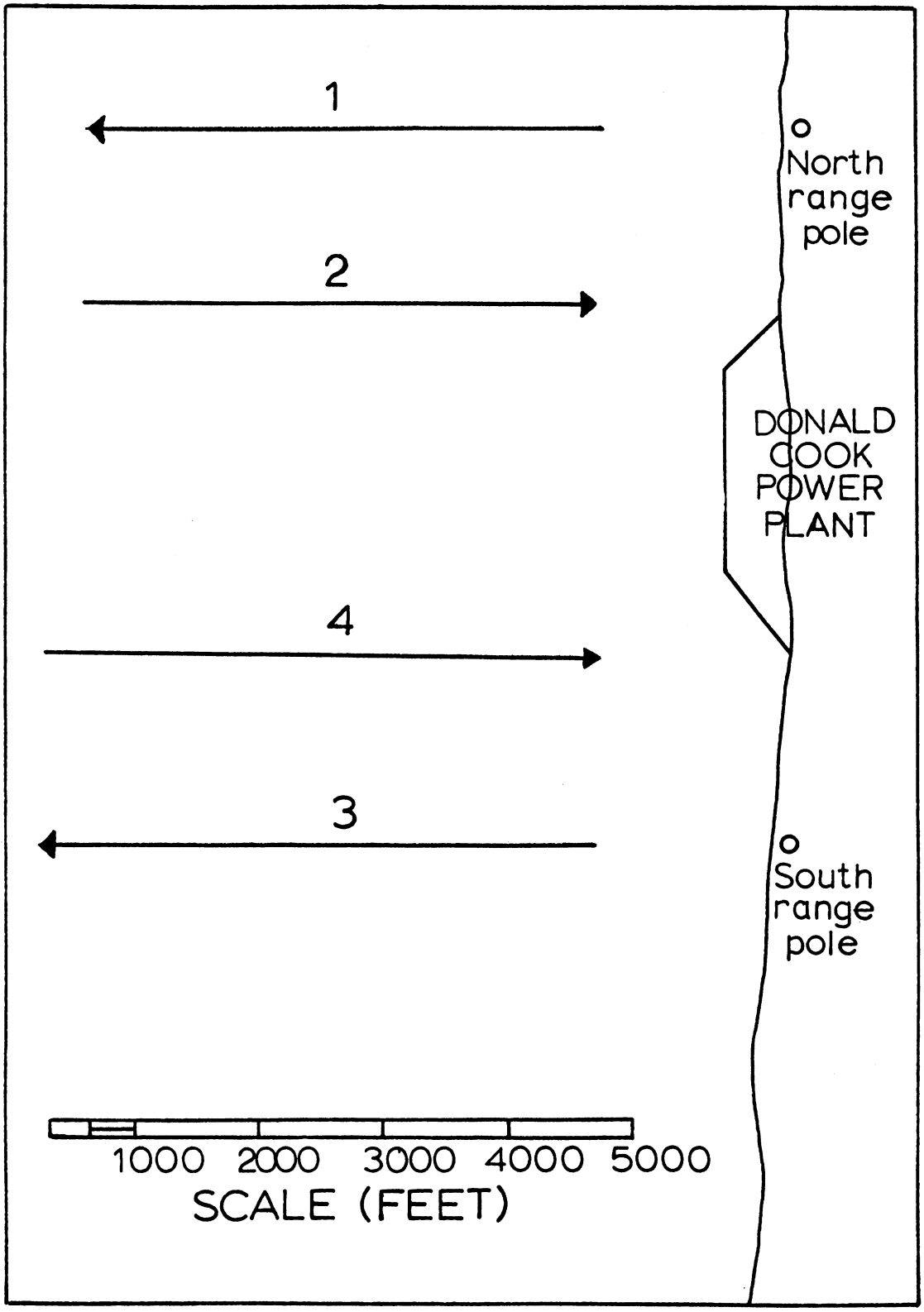

Figure 10. Location of transects for macrophyte survey.

feet south of transect 1. Transect 3 starts at a depth of 18 feet and continues offshore directly in line with the South Range pole out to a depth of 50 feet. Transect 4 starts at a depth of 50 feet and proceeds shoreward to a depth of 15 feet.

Diver observations are relayed to the support vessel and collections of any rooted macrophytes encountered are made for later identification in the laboratory.

This survey has been supplemented with a standard monthly underwater observation (daylight dives and night dives). Although the supplemental diving is not totally oriented to the macrophyte collection one element in the diving operations will be the location and collection of aquatic macrophytes. The supplemental dives are described below.

Fish

Stations

Field method. Seven stations were established in the area of the Cook Plant and Warren Dunes (control location). Two seining stations (A and B) north and south of the plant and two gillnetting and trawling stations (C and D) in 20 and 30 feet of water were established in the vicinity of the Cook Plant. At Warren Dunes State Park (control location) one seining station (F) and two deeper water (20 and 30 feet) stations (G and H) were established for gillnetting and trawling. Fish larvae tows are conducted at all seven stations. The fishing areas at the plant are shown in Figure 11.

Beach Seining

Field method. Beach seining is conducted during periods of reduced wave height using a 38.0 meter x 1.8 meter (125 feet x 6 feet) nylon bag seine having 0.5 cm (0.25 inch) bar mesh. The seine is first stretched perpendicular

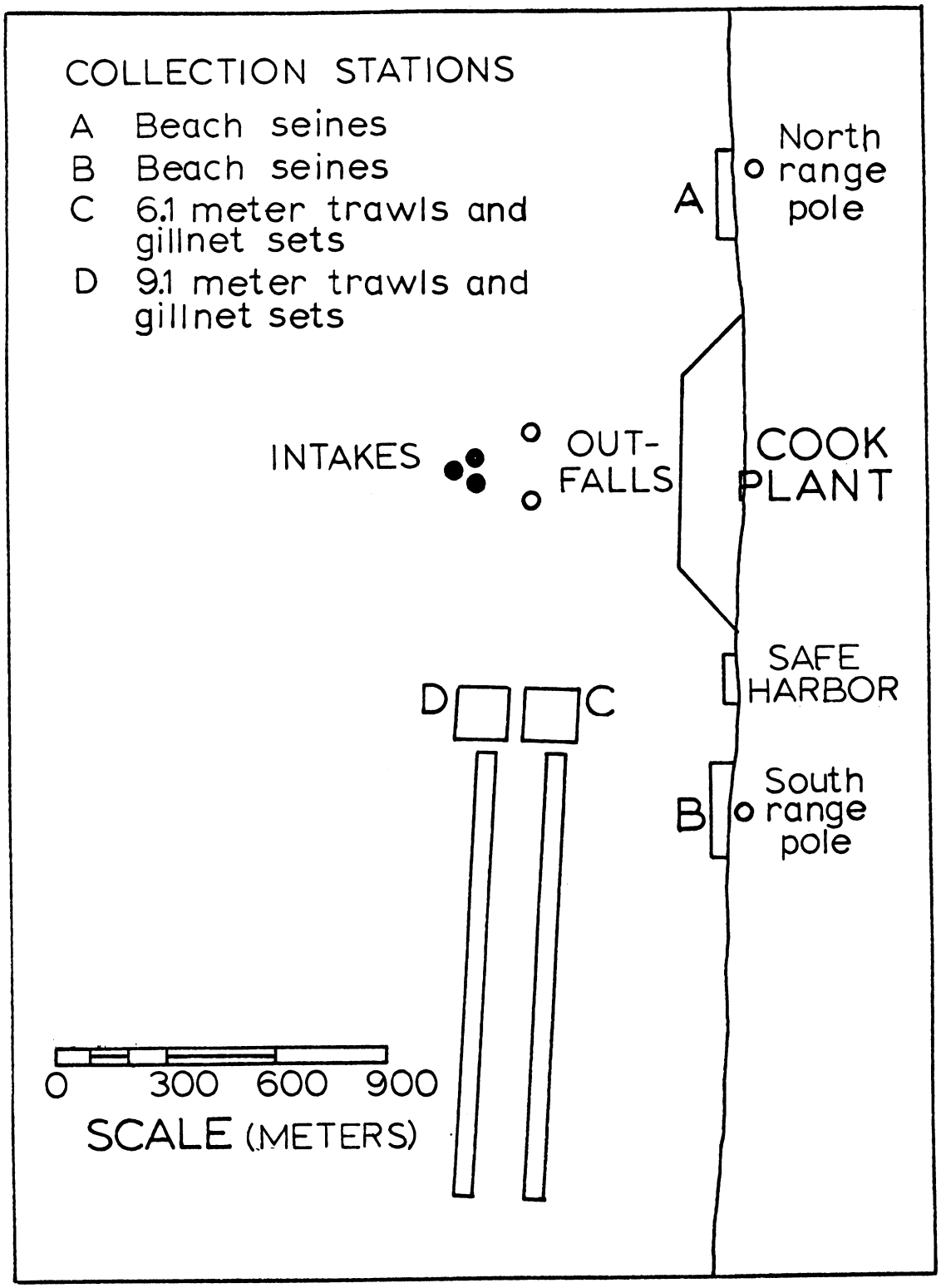

Figure 11. Map of the area showing locations of the Cook Plant, intake and discharge structures, and seining (A,B), gillnetting and trawling (C,D) stations. Seining station (F) and gillnetting and trawling stations (Ga and H) at Warren Dunes State Park (Control location) are not shown.

to the shoreline and then pulled parallel to the shore a distance of 61 meters (200 feet). Duplicate non-overlapping collections are made in this manner during a day and a night once each month at the seining stations (A,B,F). The seine is pulled against the current and southerly when no current is detectable. Fish captured by seine (also by trawl and gillnet) are placed in plastic bags and frozen for future laboratory analysis.

Trawling

Field method. Duplicate bottom tows of 10 minutes each are taken during both the day and night once per month at the four deepwater stations (C,D,G,H) using a semi-balloon nylon trawl having a 4.9 m (16 feet) headrope and a 5.8 m (19 feet) footrope. The body of the net is composed of 3.8 cm (1.5 inches) stretch mesh, the cod-end of 2.3 cm (1.25 inches) stretch mesh, and the inner liner of 1.3 cm (0.5 inch) stretch mesh. All trawls are made at an average speed of 3 miles per hour. The trawl is towed parallel to the shore following the 20 and 30 foot depth contours, one replicate going approximately north to south and the other south to north.

Gillnetting

Field method. Nylon experimental gillnets, 160.1 m x 1.8 m (525 feet x 6 feet) are set at the deepwater stations (C,D,G,H) at least once per month for approximately 12 hours during daylight and 12 hours during the night. The net is composed of 12 panels of netting as follows: three 7.6 m (25 feet) sections of the following bar mesh sizes - 1.3 cm (0.5 inch), 1.9 cm (0.75 inch), and 2.5 cm (1.0 inch) and nine 15.3 m (50 feet) sections of bar mesh sizes starting at 3.1 cm (1.25 inches) and increasing to a 7.6 cm (3 in.) including one section of 10 cm (4 in.) mesh. All nets are set parallel to shore on the bottom.

Fish Larvae

Field method. A one-half m diameter plankton net of No. 2 mesh (351μ aperature) is used to collect fish larvae. Samples from all seven stations are collected during the day and at night once per month. Four five-minute tows parallel to shore at an average speed of 2-4 miles per hour are conducted at each deepwater station. These tows consist of a steptow of the bottom (100 seconds at 3, 4 and 5 m for the 6.1 m stations; 100 seconds at 4, 6 and 8 m for the 9.1 m stations), and one 5-minute tow each at 2, 1 and 0 m. For the inshore stations (A,B,F) a set of duplicate samples are obtained by towing the net by hand north to south, then south to north, a distance of 100 feet once during the day and once at night in a depth of 3-4 feet. All samples are immediately preserved using 10 percent formalin. A flowmeter attached to the center opening of the net permits calculation of the volume of water sampled.

Laboratory method. Fish from seines, gillnets and trawls are thawed as needed at the laboratory, separated by species, then grouped according to size classes. When large numbers of a particular species are present, a subsample is randomly selected, and a mass weight of the remaining group is taken. Length, weight, sex, gonad condition, as well as fin clips, lamprey scars, and evidence of disease and parasites are noted for these fish on a coding form which goes directly to a keypuncher for later data analysis. Preserved fish larvae are identified, counted and numbers per cubic meter determined. The same samples examined for larvae are also examined for fish eggs.

IMPINGEMENT AND ENTRAINMENT STUDIES

It is anticipated that prior to the actual operation of the plant, i.e. at the time the plant is pumping water without a warm water plume, the tech-

niques to be used will be tested for accuracy and sampling representativeness. The preoperational work will include testing for vertical and horizontal stratification and determination of exact sampling location within the forebays.

The impingement and entrainment study will be made in the preoperational phases for the period starting in early 1974 and continue for one year. This will allow investigation of mechanical damage to organisms and comparison with mechanical damage and heat when the plant is in power production.

Should the plant be allowed to go on line when this phase of the study is being conducted the impingement-entrainment program outlined here will be continued for one year after the initial start up.

Impingement of fish

Daily collection of fish impinged on the travelling screens will be made for six months starting with first sustained operation of the pumps in 1974. These data will be analyzed statistically to determine if collection of samples every fourth day rather than daily would still be statistically valid. Should statistics verify the validity of the every fourth day sampling scheme then fish will be collected for a twenty-four hour period every fourth day after the initial six-month test period.

Fish will be collected in fish collection baskets and examined for species, life stage, and quantity (weight) collected. A representative subsample of each species will be counted, measured, weighed, sexed, and breeding and general condition determined. If possible, dead fish in the area ahead of the intake screens will be noted.

Fish entrainment and entrainable benthos

Fish, fish larvae, fish eggs and benthos will be sampled at two locations: in the intake forebay and discharge forebay following passage through the

condensers. Netting within and outside the plume is anticipated for fish larvae and adults. Testing will be done during 1974, to determine existence or nonexistence of vertical and horizontal stratification in the intake forebay; three depths will be sampled: near the bottom, at mid-depth and near the surface. If stratification is not observed sufficient samples to meet statistical reliability will be taken in each forebay.

Forebay samples will be taken by pumping measured volumes of water with a 80 gpm diaphram pump into a 1/2 m plankton net #2 (351 micron mesh). The net will be suspended in a barrel of water in an upright position to prevent damage to organisms from impingement against the net.

Samples will be collected twice monthly three times for 8 hours each time during a twenty-four hour period. Fish larvae will be sorted by species and enumerated. Living-dead distinctions will be performed on samples collected at shorter time intervals. Methods for the rapid distinction (under field conditions) between living and dead larvae are still in the developmental stage. The same samples collected for fish eggs and larvae are inspected for benthic organisms.

Zooplankton entrainment

Zooplankton samples will be collected in the intake forebay, discharge forebay following passage through the condenser, and within the plume. Within the intake and discharge forebays the sample will be collected by pumping water (with volume of water pumped being recorded) through a #10 plankton net suspended in a barrel of water. Plume samples for zooplankton will be taken by vertical tows through the water column with a flowmeter in the net mouth.

After preliminary experiments to determine whether horizontal or vertical stratification exist and to choose a representative sampling position replicate

samples will be collected monthly. Testing will be accomplished in 1974 when the plant is pumping water without having a warm water plume. Care will be taken in the handling of the samples to preclude damage to organisms. The samples will be collected during one twenty-four period a month at four times during the day: mid-morning, mid-afternoon, late evening and late night to determine diurnal variation. Variations are lagged behind sunrise and sunset.

The laboratory techniques described above will be employed for the zooplankton with the exception that selected samples will, in addition, be counted for live and dead organisms as soon as possible after collection. Further studies will use incubated samples to determine survivorship of entrained zooplankton over periods up to twenty-four hours after return to ambient water temperatures. A tentative sampling schedule for a 360-day study of entrained zooplankton is given in Table 6.

Phytoplankton entrainment

Phytoplankton samples will be collected in the intake forebay, discharge forebay following passage through the condenser, and within the plume. Sampling frequency will be monthly. Samples will be collected at three times during one twenty-four hour period in early morning, at mid-day and in late evening. Sampling intensity is dependent on the presence of a diurnal pattern; should no diurnal pattern be observed in the samples during 1974 when the plant is pumping water without having a warm water plume, one replicate sample at each of the above locations will be proposed.

The laboratory techniques will be the same as discussed above in the phytoplankton section of this report with the exception that in addition chlorophyll a and phaeo-pigment investigation will be performed (Strickland and Parsons, 1972). The ratio of chlorophyll a to phaeo-pigment will be used

TABLE 6

Tentative Sampling Schedule for a 360-day Study of Entrained Zooplankton

a = samples for which mortality is determined once, immediately after collection.
b = incubated samples, mortality determined immediately after collection, after 4 hours and after 24 hours.
x = samples for which mortality is not measured (to get the diurnal cycle).
* = sample numbers; spaced 15 days apart.

5-day nterval	PLUME	INTAKE BAY	DISCHARGE BAY			
	3 p.m.	9 a.m.	9 a.m.	2 p.m.	9 p.m.	2 a.m.
AN 1*				xx	xx	xx
2		bb	bb			
EB 3				xx	xx	xx
4		bb	bb			
AR 5				xx	xx	xx
6		bb	bb			
PR 7				xx	xx	xx
8	aa	bb	bb			
AY 9				xx	xx	xx
10		bb	bb			
UN 11				xx	xx	xx
12	aa	bb	bb			
UL 13				xx	xx	xx
14		bb	bb			
UG 15				xx	xx	xx
16	aa	bb	bb			
EPT 17				xx	xx	xx
18		bb	bb			
CT 19				xx	xx	xx
20	aa	bb	bb			
OV 21				xx	xx	xx
22		bb	bb			
EC 23				xx	xx	xx
24		bb	bb			

to assess viability. Long and short-term effects of condenser passage on phytoplankton will be studied using incubated samples to determine survivorship of entrained organisms over periods up to forty-eight hours. Comparison of samples from the intake and discharge forebays will allow assessment of effects on phytoplankton due to condenser passage.

Species composition, abundance, as well as chlorophyll a and phaeopigments will be recorded for each sample.

VISUAL OBSERVATION OF THE INTAKE AND DISCHARGE STRUCTURE AREAS

A standard monthly underwater survey during April through October using divers will be made to provide first hand knowledge of conditions in the areas about the intake and discharge structures as well as the adjacent lake bottom. Diving operations will be dependent on favorable weather conditions. The dives are intended to complement the general ecological survey.

Several dives are planned each month. Daylight and nighttime dives are scheduled. The areas of the intake and discharge structures as well as a control location outside the plume will be investigated. The diving locations will be examined and sampled for algae, periphyton, decaying material, attached macrophytes, fish, molluscs and crayfish. In the area about the discharge, scour indications will also be of concern. The night dive will be made to provide comparison between the day and night biotic conditions (including fish).

CHEMICAL INVESTIGATION OF WATER AND SEDIMENTS

The chemistry study includes analysis of lake water, stream water, sediments, interstitial water, and particulate matter. The plant may discharge both radioactive and non-radioactive materials into Lake Michigan.

In order to understand where to look for possible increased elemental concentrations due to plant effluents, pre-operational sediment surveys were conducted in September and October 1973. Figure 12 shows the detailed grid used in the surveys. These surveys will be used to determine background concentrations of each species, to locate areas of ferromanganese coating and organics, and to determine areas of sediment affected by other high concentration sources, such as the St. Joseph River. Field descriptions and measurements of Eh, pH, and temperature of sediments were done. These sediments will be analyzed for Cu, Fe, Total-P, Na, Ca, Mg, Mn, Cr, Zn, Sr, Mo, Ni, Ba, Co, inorganic carbon,

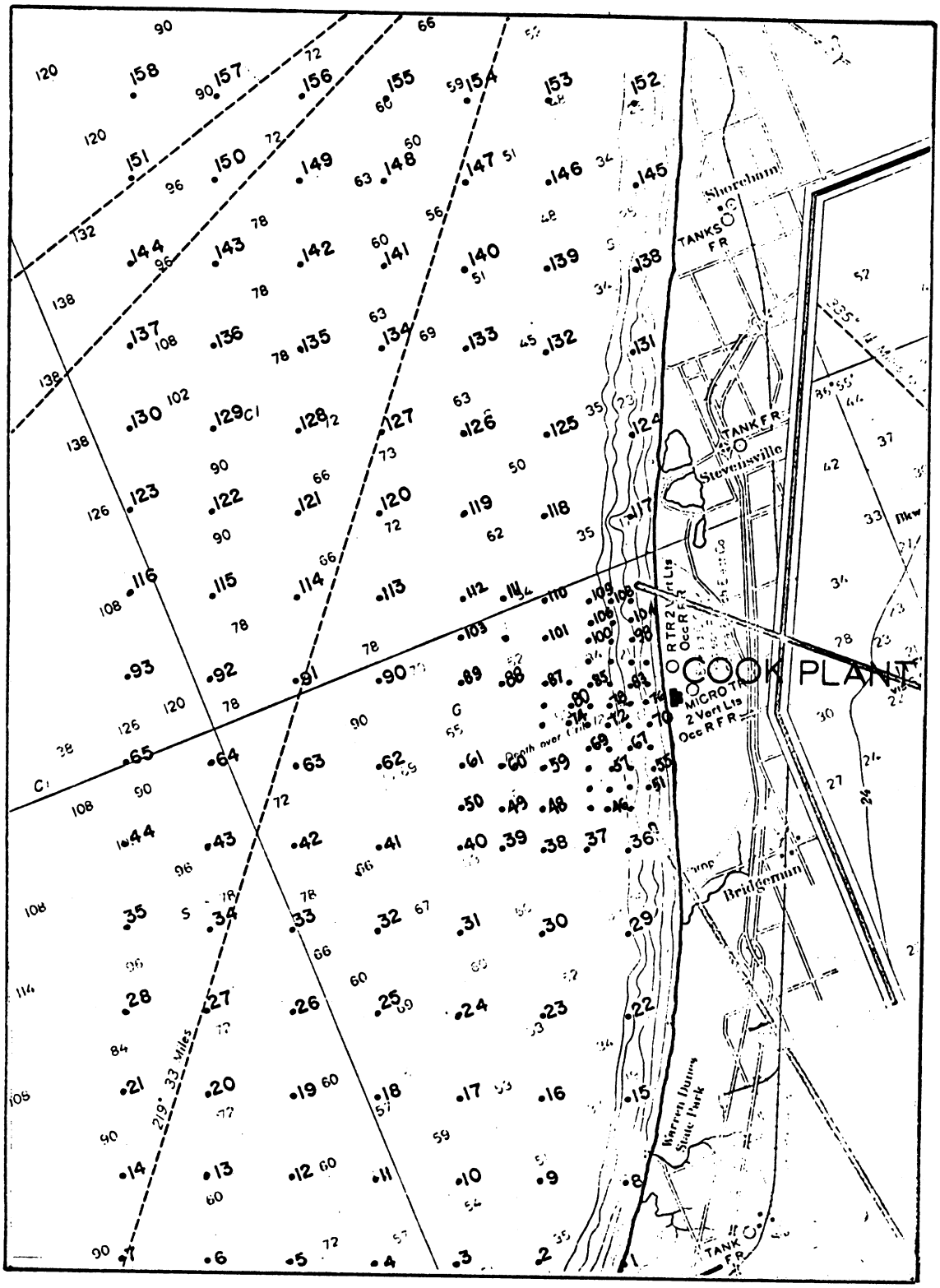

Figure 12. Grid used for sediment chemistry surveys - September and October 1973.

organic carbon and total carbon.

Lake and stream waters will be analyzed for chloride, Cu, Fe, soluble phosphorus, total phosphorus, total dissolved solids, hardness, dissolved silica, sulfate, Na, Ca, Mg, Mn, Cr, Zn, Sr, Mo, and Ni. Ba and Co measurements will be attempted; however, both Ba and Co analyses suffer from extreme calcium interferences. Field measurements of pH, Eh, dissolved oxygen, and alkalinity will also be done. All water samples will be filtered. The particulate trapped on the filters will be analyzed for the same variables as the water.

Phosphate and dissolved silica will be analyzed colormetrically, sulfate turbidimetrically, hardness and chloride with specific ion electrodes, total dissolved solids gravimetrically, all major and minor elements by atomic absorption spectrophotometry, and trace elements by atomic absorption spectrophotometry using a graphite furnace attachment.

Analysis of the sediments started in October 1973. Water samples will be collected to coincide with a variety of meteorological conditions on a regular basis beginning in 1974. Interstitial fluids will be collected starting April 1974.

Chemistry Sampling Procedures and Analytical Methods

Sediment

Field measurements of Eh, pH, and temperature are made on sediment samples immediately after collection. All pH measurements are made using a rugged pH electrode and a calomel fiber junction saturated KCl reference electrode. Standardization for the measurements are made using commercially available pH buffer solutions. Eh measurements use the same reference electrode and a platinum inlay electrode. Standardization is against Zobell's solution (Zobell 1946). Temperature measurements are made with a standard glass laboratory thermometer

by inserting it into the sediment. After field descriptions are made, the sediment is stored in polyethylene bags for laboratory analysis. In the laboratory, the samples are oven dried at 110°C. Samples for major, minor, and trace element analyses will be dissolved in a hot (near boiling) 10% HCl-30% H_2O_2 solution. Analyses for Ca, Mg, Na, K, Mn, Fe, Cu, Co, Ni, Mo, Ba, Cr, Sr, and Zn are done by standard atomic absorption spectrophotometry techniques (Perkin Elmer 1968). Phosphorus are done by extraction of molybdenum heterolpoly acids and measurement for Mo by atomic absorption spectrophotometry (Ramakrishna, et al. 1969).

Total carbon analyses are done on oven dried samples using a LECO carbon analyzer. Inorganic carbon are measured using a modification of the LECO carbon analyzer system (Kolpack and Bell 1968). Organic carbon is considered to be equal to total cargon minus inorganic carbon.

Water

Measurements of Eh, pH, dissolved oxygen, temperature, and alkalinity will be made on all stream and lake water samples collected. Eh and pH will be made using the previously discussed electrodes. Oxygen and temperature measurements will be obtained with a combination oxygen/temperature meter. Akalinity will be done by adding 1-5 ml of 0.01N HCl to 20 ml of sample and reading the pH which must fall between 3 and 4 (Kramer 1968). Samples for PO_4^{2-}, dissolved silica, SO_4^{2-}, Cl^-, total hardness, and total residue will be stored in polyethylene bottles in a refrigerator and analyzed the following day for PO_4^{2-} (Sutherland, et al. 1966), dissolved silica (Sutherland et al. 1966), and SO_4^{2-} (Standard Methods). Concentrations of chloride and total hardness will be made by standard addition techniques using specific ion electrodes. Total residue will be done gravimetrically (Standard Methods).

Samples for major, minor, and trace element analyses will be filtered through 0.45 um filters, acidified with nitric acid, and stored in polyethylene bottles. The filters will be stored in glass vials for particulate matter analysis. Analysis of particulate matter will require the same techniques as those used for sediment analysis. Ca, Mg, Na, and K in the water will be measured using standard atomic absorption spectorphotometry techniques (Perkin Elmer 1968) and Cu, Fe, Mn, Cr, Zn, Sr, Mo, Ni, Ba, and Co will be done using a graphite furnace attachment on the atomic absorption spectorphotometer.

Interstitial Fluids

Interstitial fluids will be recovered from their associated sediments by dialysis using apparatus to be designed and built by the Great Lakes Research Division (prototypes have been successful). Analyses for Ca, Mg, Na, K, PO_4^{2-}, SO_4^{2-}, Fe, and Mn will be done as previously described for lake water with the exception that Fe and Mn will not require the graphite furnace.

SUMMARY AND CONCLUSION

The program of studies related to the Donald C. Cook Nuclear Plant has gone through several stages of development. It started with a familiarization and ended up being perhaps the most extensive, comprehensive, detailed and thorough study of the environment in this part of Lake Michigan.

The entire pre-operational portion of the program was designed around the goal of establishing a base from which environmental changes could be ascertained. The natural variations that occur in the area are large and it, therefore, would be unrealistic to believe that every minute change will be detectable. But, because of this, the general ecological survey at the Cook Plant was designed broad in scope, amibitous in the area of the lake investigated and covers a wide range of biota.

The program provides, in addition to the lake environment study, a study of what happens to the biota on its passage through the plant. Little is known about that but the program is designed with the anticipation that data will be provided on the influence of condenser passage effects on the plankton, fish eggs and larvae. This data will enable an estimation of the severity of plant-induced effects.

All in all, the studies unique features: long-term, wide study area, frequent sampling, multiple sample analysis and low level of identification will enable the determination of significant long-term changes. But, perhaps one of the most important contributions of the study to date has been to provide data and discussion of data for other investigators to read and use. A list of reports that have been the direct result of this study follows.

Special Report 44

BENTON HARBOR POWER PLANT LIMNOLOGICAL STUDIES

PART

I Ayers, John C., and Joseph C. K. Huang. November 1967. General Studies, 1966 & 1967. Great Lakes Res. Div., Univ. of Michigan. 37 p.

II Ayers, John C., Alan E. Strong, Charles F. Powers, and Ronald Rossmann. December 1967. Studies of Local Winds and Alongshore Currents. Great Lakes Res. Div., Univ. of Michigan. 20 p.

III Krezoski, John R. April 1969. Effects of Power Plant Waste Heat Discharge on the Ecology of Lake Michigan, 1968. Great Lakes Res. Div., Univ. of Michigan. 47 p.

IV Ayers, John C., Robert F. Anderson, Norbert W. O'Hara, and Charles C. Kidd. 1970. Cook Plant Preoperational Studies, 1969. Great Lakes Res. Div., Univ. of Michigan. 92 p.

V O'Hara, Norbert W., Robert F. Anderson, William L. Yocum, and John C. Ayers. April 1970. Winter Operations, March 1970. Great Lakes Res. Div., Univ. of Michigan. 11 p.

VI Kidd, Charles C. 1970. *Pontoporeia affinis* (Crustacea, Amphipoda) as a Monitor of Radionuclides Released to Lake Michigan. Great Lakes Res. Div., Univ. of Michigan. 71 p.

VII Ayers, John C., Dean E. Arnold, Robert F. Anderson, and H. K. Soo. March 1971. Cook Plant Preoperational Studies 1970. Great Lakes Res. Div., Univ. of Michigan. 72 p. + Appendix 13 p.

VIII Ayers, John C., Norbert W. O'Hara, and William L. Yocum. June 1971. Winter Operations 1970-1971. Great Lakes Res. Div., Univ. of Michigan. 37 p.

IX Ayers, John C., William L. Yocum, H. K. Soo, Thomas W. Bottrell, Samuel C. Mozley, and Luis C. Garcia. March 1972. The Biological Survey of 10 July 1970. Great Lakes Res. Div., Univ. of Michigan. 72 p.

X Ayers, John C., H. K. Soo, and William L. Yocum. August 1972. Cook Plant Preoperational Studies 1971. Great Lakes Res. Div., Univ. of Michigan. 140 p. + Appendix 12 p.

XI Ayers, John C., and William L. Yocum. September 1972. Winter Operations 1971-1972. Great Lakes Res. Div., Univ. of Michigan. 22 p.

XII Jude, David J., Thomas W. Bottrell, John A. Dorr, III, and Timothy J. Miller. March 1973. Studies of the Fish Population Near the Donald C. Cook Nuclear Power Plant, 1972. Great Lakes Res. Div., Univ. of Michigan. 115 p. + Addendum 12 p.

Special Report 44 (cont.)

PART

XIII Ayers, John C., and Erwin Seibel. March 1973. Cook Plant Pre-Operational Studies 1972. Great Lakes Res. Div., Univ. of Michigan. 281 p.

XIV Ayers, John C., William L. Yocum, and Erwin Seibel. May 1973. Winter Operations 1972-1973. Great Lakes Res. Div., Univ. of Michigan. 22 p.

XV Ayers, John C., Samuel C. Mozley, and James C. Roth. July 1973. The Biological Survey of 12 November 1970. Great Lakes Res. Div., Univ. of Michigan. 69 p.

XVI Seibel, Erwin, James C. Roth, John A. Stewart, and Susan L. Williams July 1973. Psammolittoral Investigation 1972. Great Lakes Res. Div., Univ. of Michigan. 63 p.

XVII Ayers, John C., and Erwin Seibel. December 1973. Program of Studies Related to the Donald C. Cook Nuclear Plant. Great Lakes Res. Div., Univ. of Michigan. 57 p.

XVIII Johnston, Edward M. December 1973. Effects of a Thermal Discharge on Benthos Populations: Statistical Methods for Assessing the Impact of the Cook Nuclear Plant. Great Lakes Res. Div., Univ. of Michigan. 20 p.

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